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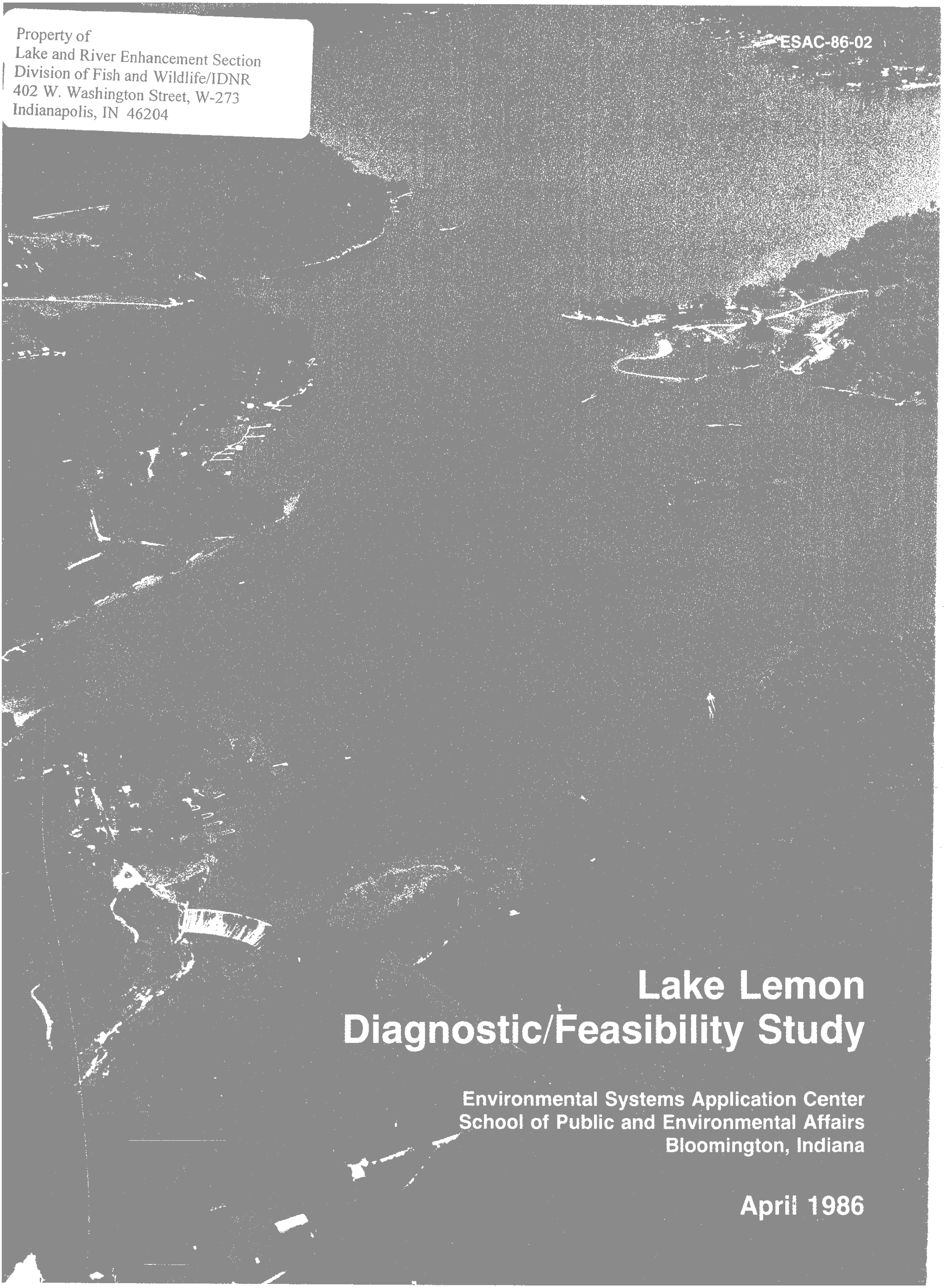

Lake Lemon Diagnostic/Feasibility Study

Environmental Systems Application Center
School of Public and Environmental Affairs
Bloomington, Indiana

April 1986

ESAC-86-02

LAKE LEMON DIAGNOSTIC/FEASIBILITY STUDY

Prepared By

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April 1986

DISCLAIMER

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TABLE OF CONTENTS

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We would also like to thank the Lake Lemon Civic Association for their assistance and cooperation, and particularly George Calvert and Bob Hart who recorded lake level changes from staff gages attached to their piers.

Graphics for this report were prepared by Keith Bobay and William Jones. Pam Duitsman and Joan Wiggins typed and corrected the final manuscript through its many versions.

SUMMARY

1. Lake Lemon is a 583 hectare (1,440 acre) reservoir located in northeastern Monroe County, Indiana. The reservoir is shallow, with a maximum depth of 8.5 meters (28 feet) and a mean depth of 2.9 meters (9.7 feet).

2. Lake Lemon was constructed in 1953 for flood control, recreation, and as a drinking water supply for the City of Bloomington. The City of Bloomington owns the reservoir but does not use it for drinking water at this time.

3. Lake Lemon has a large (182 km^2/70 mi^2), mostly forested drainage basin characterized by steep topography. About 80% of the drainage basin is drained by Beanblossom Creek and its tributaries. Lake Lemon's hydraulic flushing rate was calculated as 5 times/year for the 1982 water year.

4. Turbidity in Lake Lemon is high following storm events. Most of the suspended material settles out in the eastern end of the lake where sedimentation is a problem. Little sedimentation has occurred in the lake's western end.

5. Lake Lemon has a largely meromictic circulatory pattern. The only stratification observed occurred in the original streambed of Beanblossom Creek which accounts for only 5% of the total lake volume. Dissolved oxygen was limiting in these bottom waters in late summer.

6. The nutrient budget for Lake Lemon suggests that there is little net deposition of phosphorus in the lake and, to the contrary, there may be some export of phosphorus from the lake. Most phosphorus enters the lake in particulate form from Beanblossom Creek. On-site septic systems were judged to be a minor source of phosphorus input.

7. High concentrations of fecal coliform bacteria were measured in the Chitwood Addition and lower Beanblossom Creek. This indicates failing on-site septic systems. Corrective action should be taken.

8. Algal biomass in Lake Lemon was relatively low except for a five-week period in late summer when a blue-green bloom occurred.

9. The major water quality problem in Lake Lemon is the dense growth of the aquatic macrophyte *Myriophyllum spicatum* (Eurasion water milfoil) which was found in nearly all waters of the lake having a depth between 0.75 and 3 meters (2.5 - 10 feet). The dense growths restrict boating and swimming activities.

10. Lake Lemon's fisheries are healthy with a large proportion of "keepable" bass and other game fish. Forage fish are in abundant supply.

11. Runoff and streambank erosion controls are recommended where needed in Lake Lemon's drainage basin. However, a Soil Conservation Service watershed assessment concluded that erosion from agricultural lands, in general, is not excessive.

12. In-lake management techniques recommended include shoreline stabilization and *Myriophyllum* control. Lake drawdown is recommended to control *Myriophyllum*; however, problems with the outlet's low discharge capacity and high runoff variability reduce its effectiveness. Mechanical harvesting of *Myriophyllum* is recommended over chemical treatment as a supplement to lake drawdown.

13. Lake Lemon homeowners must take a more active role in protecting and managing the lake. Areas where homeowners can help include properly maintaining on-site septic systems, stabilizing eroding lakeshore areas, and controlling *Myriophyllum* in shallow areas along piers and beaches by hand cutting and removal, using vegetation screening material and raking tubers during drawdown conditions.

METRIC TO ENGLISH CONVERSIONS

Metric	English
centimeter (cm)	0.39 inch
meter (m)	3.28 feet
kilometer (km)	0.62 mile
hectare (ha)	2.47 acres
square kilometer (km^2)	0.39 square mile
liter (l)	1.06 quarts
cubic meter (m^3)	1.31 cubic yards or 0.0008 acre-feet

CHAPTER 1: INTRODUCTION

Lake Lemon was constructed by the City of Bloomington in 1953, in a hilly, heavily wooded drainage basin, by impounding Beanblossom Creek. The lake is used currently for flood control, low-flow augmentation, recreation, and as a supplemental drinking water supply for the City of Bloomington.

For many years Lake Lemon has provided valuable recreational opportunities for many residents of south central Indiana. Boating, sailing, fishing, and swimming are all popular activities. However, the lake water quality has deteriorated sufficiently overtime to cause concern to the local citizens and city officials. Today, the lake suffers from decreased water clarity, sedimentation, shoreline erosion, and dense growths of nuisance aquatic macrophytes. These conditions have impaired recreational uses of Lake Lemon.

Deteriorating lake conditions led to the formation of the Lake Lemon Civic Association (LLCA), a group of concerned citizens living on and near the lake. The purpose of the association is to address the major water quality problems of the lake. The LLCA has worked with the City of Bloomington on a chemical-based macrophyte control program. In 1979, the City of Bloomington spent $58,000 to chemically treat the heavy growths of macrophytes. Another $38,000 was used from 1980 through 1982 to pay for additional chemical treatments. These funds were generated by citzen contributions and through the yearly lake frontage fee assessed on owners of lakeshore homes by the City of Bloomington.

Recognizing that a more coordinated and comprehensive lake management program was needed, representatives of the City of Bloomington and the Environmental Systems Application Center (ESAC) at Indiana University's School of Public and Environmental Affairs (SPEA), met to discuss options for Lake Lemon. An application for a Phase I Diagnostic/Feasibility Study Grant from the U.S.

Environmental Protection Agency's Clean Lakes Program, under which the present project was conducted, was the outgrowth of these meetings.

CHAPTER 2: LAKE SETTING

2.1 LOCATION

Lake lemon is located on the boundary between Monroe and Brown Counties, approximately nine miles northeast of Bloomington, Indiana (Figure 2-1). It lies primarily within sections 27, 28, 33, 34, 35, and 36, T10N, R1E; and section 31, T10N, R2E. Lake Lemon is bounded on the south by South Shore Drive, on the east by state highway 45, and on the north by North Shore Drive (Figure 2-2)

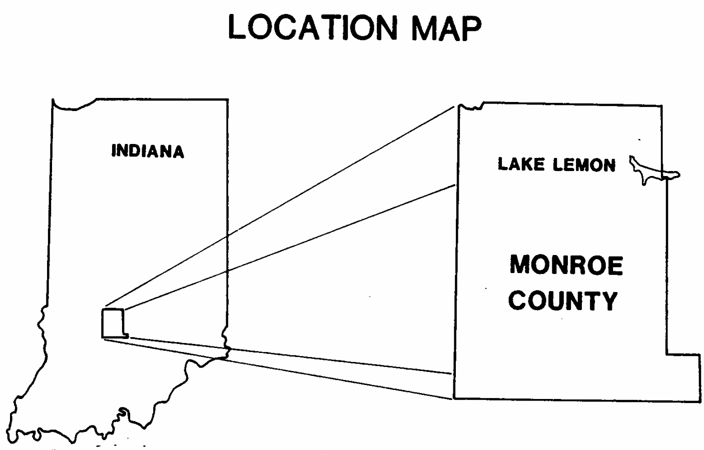


Figure 2-1. Location Map

2.2 LAKE MORPHOMETRY

Lake Lemon has an elongated shape running west to east that is divided roughly into three lobes by two peninsulas known as Riddle Point and Reed

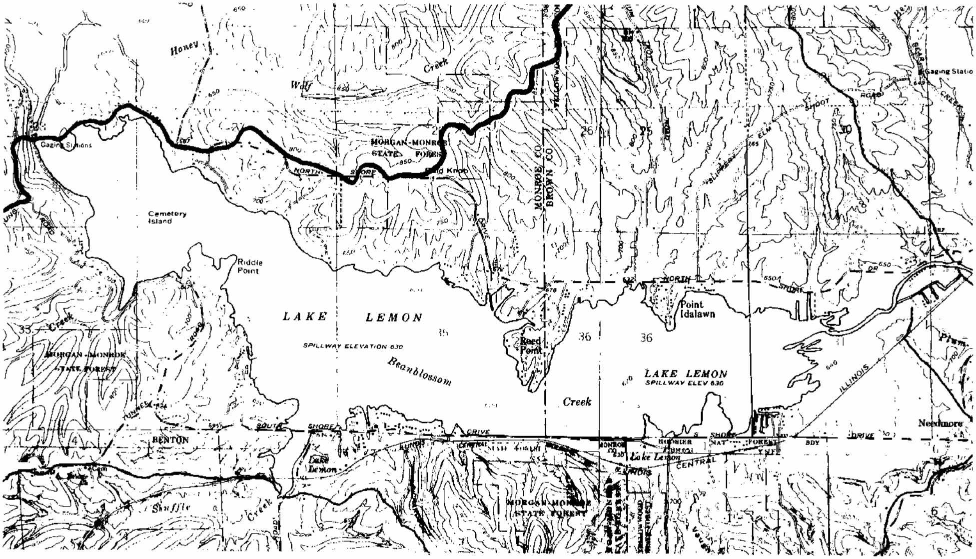


Figure 2-2. Topographic map of Lake Lemon. Drainage basin and sub-basin boundaries are indicated.

TABLE 2-1. LAKE LEMON MORPHOMETRY

Maximum Length	6.5 km (4.0 miles)
Maximum Width	1.5 km (0.9 miles)
Surface Area	583 hectares (1,440 acres)
Volume	17,100,000 cubic meters (13,900 acre-feet)
Maximum Depth	8.5 meters (28 feet)
Mean Depth	2.9 meters (9.7 feet)
Shoreline	24 km (14.9 miles)

Point. Morphometric parameters for Lake Lemon are presented in Table 2-1 and Figure 2-3.

2.3 DRAINAGE BASIN SIZE AND CHARACTERISTICS

Lake Lemon drains a hilly and predominantly wooded area of approximately 182 km^2 (18,200 ha) or 70.2 mi^2 (44,900 acres) in size, including the lake area (Figure 2-4). This results in a rather large drainage area to lake area ratio of 31:1. Of the total drainage basin, 88% (160 km^2) lies in Brown County, 12% (21 km^2) in Monroe County, and < 1% (0.5 km^2) in Johnson County.

There are no large towns in the Lake Lemon watershed, only small villages (Trevlac, Helmsburg, Beanblossom, Fruitdale, and Spearsville).

Lake Lemon receives runoff primarily from Beanblossom Creek and its tributaries, which drain 81 percent of the watershed. Supplementary runoff is received from several small streams and directly from the immediately surrounding forested ridges. Table 2-2 lists the drainage areas of the individual basins within Lake Lemon's watershed.

The only outlet from Lake Lemon is Beanblossom Creek and flow from the lake is controlled. Water is discharged over the spillway (elevation 630 MSL) when the lake level is high or can be released through an outlet structure that draws water from the lake's bottom waters.

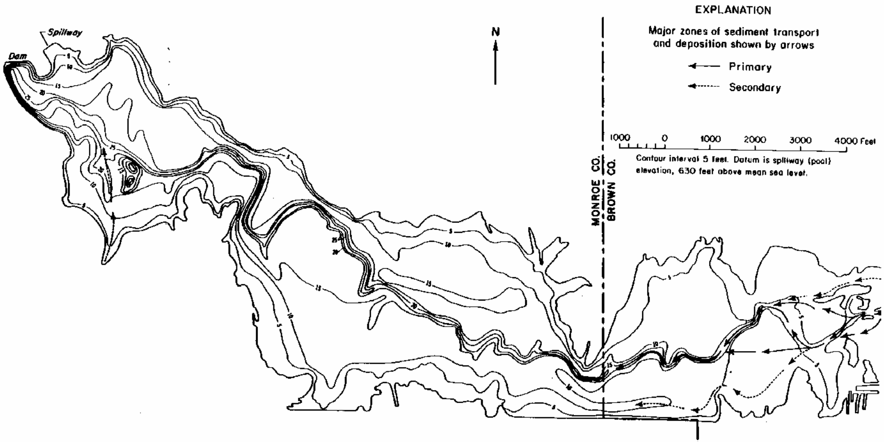


Figure 2-3. Map of Lake Lemon showing water depth.
From: Hartke and Hill (1974).

TABLE 2-2. SUB-BASIN DRAINAGE AREAS WITHIN LAKE LEMON'S WATERSHED

Sub-Basin	Area km^2	mi^2
North Fork Beanblossom Creek	33.4	(12.9)
Lick Creek	16.3	(6.3)
Brier Creek	7.3	(2.8)
Bear Creek	19.7	(7.6)
Plum Creek	11.1	(4.3)
Slippery Elm Shoot Creek	1.6	(0.6)
Beanblossom Mainstem	58.8	(22.7)
Total Beanblossom Creek	148.1	(57.2)
Possumtrot Creek	3.9	(1.5)
Rapid Creek	2.1	(0.8)
Shuffle Creek	6.7	(2.6)
Other drainage	15.0	(5.8)
Lake Lemon	6.0	(2.3)
TOTAL LAKE LEMON WATERSHED	181.8	(70.2)

2.4 GEOLOGY

Lake Lemon and its drainage basin lie in the Norman Upland physiographic province, a severely dissected plain. Long narrow ridges with steep slopes descend into V-shaped ravines or form narrow valleys with nearly flat bottoms (Schneider 1966). Topography is most rugged along the southern border of the watershed, and only slightly less rugged in the northwestern quadrant. Elevations range from 192 meters (630 ft) above MSL (elevation of the spillway of Lake Lemon) to 315 meters (1033 ft) at Bearwallow Hill (4 km ESE of the Village of Beanblossom). Ridgetops of 260-275 meters are common, whereas all major bottomlands lie below 230 meters, and most below 220 meters. Hence, local topographic variations of 30-60 meters are common throughout the watershed (see the Beanblossom, Belmont, Hindustan, Morgantown, Nashville, and Unionville 7.5 minute U.S. Geological Survey quadrangle maps).

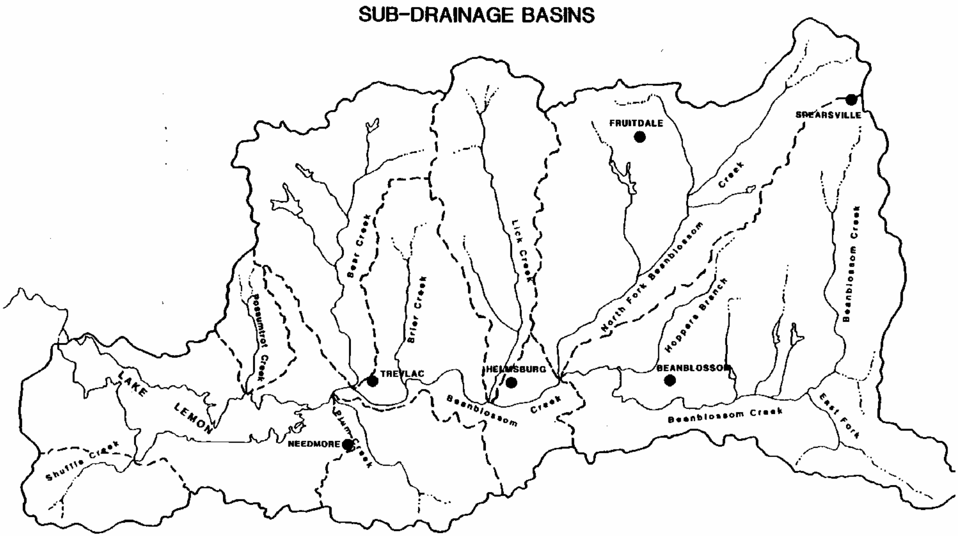


Figure 2-4. Lake Lemon drainage basin.

The Norman Upland was formed from rocks of the Borden Group of the Mississippian geologic age (Schneider 1966). The upper strata consist of weather-resistant siltstones interbedded with shales and thin limestones (Muldraugh and Carwood Formations). These rocks overlie sandstones with some siltstones and shales (Locust Point Formation), which overlie the nonresistant New Providence Shale (Shaver et al. 1970).

On a broad scale all of these strata dip about 12 meters per km (25 ft per mi) to the west-southwest. This places all but the southwestern quadrant of the Lake Lemon watershed on the west-southwestern flank of an east-northeast facing cuesta, with the escarpment just east of the Brown-Bartholomew county line to the east of the watershed (Wayne 1955). Locally, the southwestern quadrant of the watershed is modified by the Mount Carmel Fault. This significant structural feature tends to the north-northwest, entering the Shuffle Creek watershed, then the Shuffle Creek embayment of Lake Lemon and then leaving Lake Lemon and its watershed just east-northeast of the spillway (Wier and Gray 1961). Rocks on the western side of the fault are down thrown and the regional dip is reversed (i.e., dips ENE) over the few miles encompassing the southwestern quadrant of the watershed. This area lies on the eastern flank of the Leesville Anticline, a local feature that crests with the Unionville Dome at the extreme southwest rim of the watershed (Melhorn and Smith 1959; Shaver and Austin 1972).

There is no evidence that any movement has taken place along the Mount Carmel Fault since the late Paleozoic age (200 million years ago), nor does the fault appear to be related to other fault zones near the lower Wabash, lower Ohio, and middle Mississippi valleys, the last of which has been active recently (Melhorn and Smith 1959; Ault et al. 1980).

Surficial bedrock throughout most of the Lake Lemon watershed belongs to the Borden Group. In the eastern part of the watershed the Borden is probably represented by outcrops of the Carwood Formation, which consist of massive shaley siltstone. The Muldraugh

Formation of the Borden Group forms most of the bedrock surface. It consists mostly of siltstones and shales, but includes siliceous cherty limestones. Geodes also are a common constituent, and give persistent evidence of the Muldraugh as they accumulate along creek beds (Shaver et al. 1970). In the extreme southwestern part of the watershed a cap of Harrodsburg Limestone overlies the Muldraugh Formation. This cap follows the southwestern rim of the Shuffle Creek watershed from the Mount Carmel Fault (just east of Unionville) westward to the crest of the Unionville Dome and then northward for nearly a mile along Tunnel Road (Weier and Gray 1961).

Nearly all of the watershed east of Lick Creek and north of Beanblossom Creek was glaciated by the Illinoian Glaciation (Wier and Gray 1961). On flat hilltops unconsolidated till may be up to three meters thick; it is generally thinner elsewhere (Rogers et al. 1946). Glacial outwash consisting of clay, silt and sand forms terraces along Beanblossom Creek, particularly on the northern side. Such terraces are present on the northeastern and southeastern shores of Lake Lemon, along Reed Point and adjacent areas, and at Riddle Point. The immediate flood plain of Beanblossom Creek and its major tributaries consists of silt, sand, and gravel of recent alluvium (Wier and Gray 1961).

2.5 SOILS

2.5.1 Soils of the Watershed

Published modern soil surveys are available for Monroe County (Thomas 1981) and Johnson County (Sturm 1979). In Brown County, fieldwork for a soil survey is in progress, with part of the mapping of the Lake Lemon drainage basin completed. At present over 30 soil mapping units (Monroe Co., 13 units; Johnson Co., 6; Brown Co., 20) are represented throughout the watershed. However, the glaciated northeastern portion (in Brown County) remains largely unmapped, and probably will provide several additional mapping units.

Nearly all of the soils of the watershed are silt loams; a few are loams or channery loams. They originate from five types of parental materials: bedrock residuum, loess, glacial till, glacial outwash, and recent alluvium (Thomas 1981). An areal breakdown for the watershed gives bedrock residum and loess-covered bedrock, 75% of the area; glacial till, 8%; terrace soils on glacial outwash, 3%; and recent alluvial soils, 14%.

The abundant siltstones and shales of the bedrock erode to provide silt and some coarse fragments (channery) for development of Berks and Weikert soils on steep side slopes, Gilpin soils on moderately steep side slopes and Burnside soils along the upper ends of drainageways. The Berks, Weikert and Gilpin soils intersperce closely, and their interpretations by soils specialists in Monroe and Brown counties differ leading to slightly different soils mapping units. All of these soils are forested because the slopes are too steep to till or maintain in pasture. They occupy over 50% of the southern and eastern portions of the watershed.

Loess has contributed silt-sized particles to the soils of ridge tops. Often, both the loess and bedrock provide parent materials. Example soils of the watershed include Hosmer soils (from thick loess and various bedrock types), Bedford and Crider soils (from loess overlying limestone), and Tilsit and Wellston soils (from loess overlying shale, siltstone, or sandstone). These soils often occupy level areas and may be used for pasture and more rarely for row-crops (e.g., near Unionville, IN). An intermediate soil between the Wellston and shallower Gilpin soils ("Wellston-Gilpin variant") is common along the narrow, peaked ridge tops of the western and southern portions of the watershed.

Soils formed on Illinoian glacial till include the Muren series on level uplands, Cincinnati and Rossmayne series on hill tops, and Hickory series on side slopes. These soils are present in the north central to northeastern portions of the watershed. Muren soils are commonly tilled; Cincinnati and Hickory soils may be wooded, or used for pasture in more level areas (Sturm 1979). Lack of survey data for Brown County limits generalizations about soils formed on glacial till.

Surficial deposits of glacial outwash are generally restricted to terraces within the watershed, and often are overlain with thin layers of loess or recent alluvium. Example soils include the

Bartle, Chetwynd, Elkinsville, Parke, Pekin, and Peoga series. These soils may be tilled or used for pasture.

The principal alluvial soils of the watershed are the Haymond, Steff and Stendal series. These silt loams form the banks along much of Beanblossom Creek and its tributaries (Brown County SCS, unpublished data). These soils tend to characterize sluggish drainage courses (Thomas 1981), but are sufficiently well-drained to be tilled for rowcrops - their most abundant use within the watershed.

Soils throughout the watershed generally have low permeability (0.6-2.0 inches/hour), that can be very low (0.06 inches/hour) where fragipans (e.g., in Bartle, Hosmer, Pekin, and Tilsit soils) or clay beds (e.g., in Peoga soils) are present. The seasonal high water table lies below two meters of the land surface in most soils. Those with conditions favoring a perched water table include Bartle, Bedford, Hosmer, and Tilsit soils. Apparent high water tables at depths less than two meters below the land surface occur in Burnside, Muren, Pekin, Peoga, Steff, and Standal soils. Burnside, Haymond, Steff, and Stendal soils are subject to flash flooding (Sturm 1979; Thomas 1981).

2.5.2 Near Shore Soils

Designations of soil mapping units differ slightly from one county to the next. Most important, a few mapping units, particularly those representing complexes of two or more soils, may change names at county lines. These name changes result from disagreements between descriptions of the soils by soil mappers.

Near Shore Soils of Monroe County

Seven soil mapping units extend to the shore of Lake Lemon (excluding the dam, spillway, highway embankment, and railroad causeway) in Monroe County. The names of these soils, their extent along the shoreline, their suitably for use as septic fields, and the number of shoreline houses are given in Table 2-3. In general, steep slopes or low percolation capacity render the soils unsuitable

TABLE 2-3. SOILS[1] AND RESIDENTIAL LAND USE ALONG THE MONROE COUNTY SHORELINE OF LAKE LEMON

Map Symbol[1]	Name[1]	Physiography[1]	Shoreline Length (mi)[2]	Number of houses: Quad est. (1961-1966)[3]	Number of houses: Shoreline Count (1982)[4]	Hazard for septic tank absorption fields[1]
Ba	Bartle silt loam	terraces	0.75	3	1	severe/wet/low perc
Bkf	Berks-Weikert Complex, 29-75% slopes	steep hillsides	2.57	7	38	severe/depth/slope
Ekf	Elkinsville silt loam, 20-40% slopes	lower slopes	5.13	47	77	severe/slope
Hd	Haymond silt loam	well drained bottoms	0.25	0	0	severe/floods
PeA	Pekin silt loam, 0-2% slopes	low terraces	1.08	32	31	severe/wet/low perc
PeB	Pekin silt loam, 2-6% slopes	low terraces	0.75	1	2	severe/wet/low perc
Wmc	Wellston-Gilpin silt loams 6-20% slopes	ridge tops	0.55	0	12	moderate/depth/ slope/low perc
TOTAL			10.48	90	161	

[1]Source: Thomas et al. 1981

[2]Determined by wheel gauge on soil survey maps

[3]Counted from U.S.G.S. quandrangles

[4]Survey, this project

for use as septic fields. However, the Wellston-Gilpin silt loam has only moderate limitations and the Elkinsville silt loam series is suitable for septic fields if the slope is more gentle than 20%. Slow percolation rates suggest that groundwater seepage into the lake may be slight under most conditions.

Near Shore Soils of Brown County

Eight soil mapping units extend to the lakeshore in Brown County and two more border on the slow-moving, channelized section of Beanblossom Creek (Table 2-4). In general, wetness, flooding, and low percolation capacity render these soils unsuitable for use as septic fields. These limitations are associated with the upper ends of reservoirs, where bottomlands and low terraces are common between the shoreline and valley slopes. The Chetwynd loam is the only soil type at least moderately suitable for septic systems.

Summary of Near Shore Soils

Slow percolation and slope characteristics suggest that groundwater seepage into the lake may be slight at most. However, surface runoff, especially during storms, appear likely, and stream side flooding becomes a potential problem along Beanblossom Creek. Only 5% of the shoreline is moderately suitable for development of septic systems and this land presently includes only 9% of the housing units in the Lake Lemon watershed.

2.6 LAND USE

The following percentages of land use classes occur within Lake Lemon's drainage basin:

Forest	77%
Agriculture (including pasture)	19%
Residential	2%
Ponds	1%
Wetlands	0.6%
Campgrounds	0.3%

TABLE 2-4. SOILS AND RESIDENTIAL LAND USE ALONG THE BROWN COUNTY SHORELINE OF LAKE LEMON AND ADJACENT BEANBLOSSOM CREEK

Location Map Symbol[1]	Name[1]	Physiography[1]	Shoreline Length[2] (mi)	Number of houses: Quad est. (1961-1966)[3]	Number of houses: Shoreline Count (1982)[4]	Hazard for septic tank absorption fields[1]
Lakeshore						
Bgf	Berks, Gilpin Variant, 20-50% slopes	steep hillsides	0.04	2	4	severe/slope/depth
Bu	Burnside (Beanblossom) silt loam	bottoms	0.40	3	6	severe/floods/wet
Cdf	Chetwynd loam, 12-18% slopes	terraces	0.34	10	17	moderate/slope
DuA	Dubois silt loam, 0-6% slopes	terrace	0.51	0	0	severe/wet/low perc
HaB2	Haubstadt silt loam, 0-18% slopes	terrace	0.46	23	60	severe/wet/low perc
OtC2	Otwell silt loam, 6-12% slopes	terraces	0.79	8	32	severe/low perc
St	Stendal silt loam	bottom	0.43	0	0	severe/floods/wet
Other	Unnamed	wetland	1.42	0	0	severe/wet/floods
TOTAL			4.38	46	119	
Beanblossom Channel						
Cdf	Chetwynd loam, 12-18% slopes	terraces	0	0	1	moderate/slope
Hc	Haymond silt loam	bottom	2.24	43	64	severe/floods
Sf	steff silt loam	bottom	0.35	2	2	severe/floods/wet
St	Stendal silt loam	bottom	0.33	0	0	severe/floods/wet
Other	Unnamed	wetland	0.23	0	0	severe/wet/floods
TOTAL			3.15	45	67	
GRAND TOTAL			7.53	181	347	

[1]Brown County Soil Conservation Service, unpublished data

[2]Determined by wheel gauge on preliminary soil survey data maps

[3]Counted from U.S.G.S. quandrangles

[4]Survey, this project

The immediate shoreline of Lake Lemon has patchy developments of permanent and summer residences interspersed with undeveloped shoreline (see Figure 2-2). The density of houses ranges from acre-sized lots with houses set well back from the water to one-eighth acre lots with houses next to the water (e.g., adjacent to the canals at the southeastern end of the lake).

The dominant land use away from the lake is forest land. Agriculture occurs predominantly in the valleys and also on ridge tops. Corn is the major crop grown. Land use percentages by sub-basin are presented in Table 2-5.

TABLE 2-5. LAND USES IN THE MAJOR BASINS WITHIN LAKE LEMON'S WATERSHED[1]

Basin	Land Use (acres /%)				
	Forest	Agriculture	Residential	Ponds	Campgrounds
North Fork Beanblossom Creek	5,490/67	2,440/30	124/1	186/2	0
Upper Beanblossom Creek (east of North Fork)	7,980/69	3,270/28	141/1	140/1	63/1
Lick Creek	2,460/61	1,290/32	172/4	87/2	0
Bear Creek	4,350/90	370/8	22/ 1	58/1	54/1
Plum Creek	2,560/93	175/6	17/ 1	12/ 1	0
Beanblossom Creek (at Lake Lemon)	2,7940/76	7,565/21	510/1	486/1	117/ 1

[1]Estimated from vertical ASCS aerial photographs using a polar planimeter.

2.7 CLIMATE

The climate in northern Monroe and Brown counties is characterized by wide variations in temperature, typical of areas in the middle latitudes of the interior United States. Because the watershed is located in a hilly area (average elevation = 250 m), convectional breezes are generated during the heat of the day, and the ensuing clouds keep the temperature lower than in level neighboring areas.

The average annual wind velocity is 16 kmph (10 mph). The average monthly velocity increases through the winter to its peak in March, and decreases through the summer. Winds blow most frequently from the southwest, although the prevailing winds are northwest in one or two of the winter months.

Precipitation is distributed throughout the year. Spring and early summer precipitation exceeds slightly fall and winter precipitation, ensuring moist soils during the growing season when evaporation losses exceed precipitation.

Climatological data are summarized in Table 2-6.

2.8 DEMOGRAPHY

2.8.1 Current Population and Housing Statistics

Census Bureau data from five Numeration Districts (Table 2-7) provide a basis for estimating the numbers of people and housing units in the Lake Lemon drainage basin (Table 2-8). These districts include large portions of the drainage basin. A sixth district, in Hensley Township, includes such a small portion of the drainage basin (0.2 square miles; seven houses on aerial photographs) that Census Bureau data for it were not considered. The sums of the data in Table 2-7 provide upper estimates of the housing units, year-around residents, and certain other factors relevant to the study of water quality in the drainage basin. The table does not include data on seasonal changes in population or on the characteristics of seasonal or mobile housing units.

Estimates from quandrangle maps and aerial photographs indicate that at least 50% of the housing in each of the five major

TABLE 2-6. PRECIPITATION DATA COLLECTED AT BLOOMINGTON, INDIANA FOR PERIOD 1896-1968.

Month	Temperature (°F) Daily Max	Daily Min	Monthly	Mean Precipitation (in.)
Jan	40.1	21.9	31.0	3.81
Feb	42.3	23.1	32.7	2.83
Mar	52.7	32.5	42.6	4.56
Apr	65.1	42.6	53.9	3.92
May	75.6	52.2	63.9	4.39
June	84.0	61.2	72.6	4.21
July	88.3	64.9	76.6	3.70
Aug	86.6	63.2	74.9	3.66
Sept	80.4	56.3	68.4	3.53
Oct	69.4	44.5	57.0	2.93
Nov	56.0	34.3	45.2	3.27
Dec	41.6	24.7	33.2	3.36

Enumeration Districts lies within the drainage basin and that up to 95% of the housing in two of the districts is thus situated (Table 2-8). Additional estimates assume direct proportionality between housing, housing quality, and population in the entire district and that portion of the district within Lake Lemon is drainage basin. In general, the drainage basin contains 75-85% of each factor (housing, population, etc.) totaled over the five major Enumeration Districts (Table 2-8). In the sixth Enumeration District, the seven housing units are assumed to be year round housing with complete plumbing, and to have an occupancy level of 3.17 persons per unit, as in adjacent Hamblen Township.

TABLE 2-7

Data on Population and Housing: U.S. Census Bureau Data on Enumeration Districts Which Include Portions of the Drainage Basin of Lake Lemon

Township	Enumeration District	Persons	Total Housing Units	Occupied Year Round Housing Units	Persons Per Unit	Year-Round Housing Held for Occasional Use	For Sale, Rent, Other	Housing: Seasonal/ Migratory	Plumbing in Occupied Year-Round Housing Complete	Plumbing in Occupied Year-Round Housing Incomplete	Persons With Incomplete Plumbing
Brown County											
Hamblen	477	1,816	699	568	3.17	80	46	5	507	61	180
Jackson	478T	1,876	700	624	3.01	45	27	4	591	33	90
Jackson	478U	472	263	192	2.46	53	9	9	181	11	30
Jackson	479	1,426	816	525	2.72	169	44	78	459	66	168
Monroe County											
Benton	450	1,386	740	497	2.75	8	45	200	481	16	34
Johnson County											
Hensley	-	-	-	-	-	-	-	-	-	-	-
TOTAL		6,958	3,218	2,406		355	171	296	2,219	171	502

TABLE 2-8

Estimates of Population and Housing in the Drainage Basin of Lake Lemon

Township	Enumeration District	Persons	Percent Housing in Drainage Basin	Total Housing Units	Occupied Year-round (Households)	Year-round Housing Held for Occa-sional use	For Sale, Rent, Other	Housing: Seasonal/ Migratory	Plumbing in Occupied Year-round Housing Complete	Plumbing in Occupied Year-round Housing Incomplete	Persons with Incomplete Plumbing	Estimated Summer Population
Brown County												
Hamblen	477	1,090	60	419	341	48	28	3	304	37	108	1,252
Jackson	478T	1,782	95	665	632	43	26	4	561	31	86	1,923
Jackson	478U	236	50	132	66	26	5	5	91	6	15	312
Jackson	479	1,355	95	775	736	161	42	74	436	63	160	1,994
Monroe County												
Benton	450	821	60	444	266	5	27	120	289	10	20	1,165
Johnson County												
Hensley	-	22	5	7	7	0	0	0	7	0	0	17
TOTAL		5,306		2,442	2,048	283	128	206	1,688	147	389	6,663
%[Enumeration Districts]		76		76	85	80	75	70	76	86	77	-

2.8.2 Year-round Residents

The estimates give a basin-wide, year-round resident population of 5,306 persons in 2,048 households (Table 2-7). Residents without plumbing total 389, or 7.3% of the resident population.

2.8.3 Seasonal Population

The population probably reaches a seasonal maximum during the summer. Population estimates can be derived by populating three of the unoccupied categories of housing (year-round housing held for occasional use, seasonal housing, migratory housing) at the same levels as occupied year-round housing. This estimate gives a summer population of 6,663 persons (Table 2-8). It is probably low for several reasons including an influx of guests into housing already listed as occupied, operation of camps with seasonal housing at very high levels of occupancy, and large overnight attendance (in campers, trailers, tents) at seasonal events (e.g., the Bill Monroe Bluegrass Festival at Beanblossom). It is inappropriate to estimate the status of plumbing serving non-year-round housing on the basis of year-round housing, as provided by the census data. Seasonal housing would be much less likely to have complete plumbing.

2.8.4 Population Projections

Population projections to the year 2000 for the three townships in the Lake Lemon watershed are found in Table 2-9. Jackson Township covers more than half the watershed and should therefore be most carefully considered. The original projections, the result of statistical relationships and judgments of interested and knowledgable citizens, were compiled for the State Board of Health by the Division of Research in the School of Business at Indiana University.

Although the watershed totals are overestimated, since only parts of the townships are in the watershed, the figures are representative of expected growth in the area. The 1980 population at approximately 10,000 will expand 40% by the year 2000. This growth could reflect an increased demand on the recreational resources of Lake Lemon.

TABLE 2-9. INDIANA TOWNSHIP POPULATION PROJECTIONS[1]

Township Name	1980	1985	1990	1995	2000	Change 1980-2000	1980-2000 Percent
Benton (Monroe Co.)	2,980	3,030	3,320	3,580	3,810	920	31.8
Hamblen (Brown Co.)	3,370	3,480	3,990	4,570	5,200	1,830	54.3
Jackson (Brown Co.)	3,770	3,770	4,180	4.650	5,190	1,420	37.7
TOTALS	10,030	10,280	11,490	12,800	14,200	4,170	41.6

[1]Based on 1978 projections by Division of Research/School of Business/Indiana University; adjusted for 1980 census and rounded to nearest 10.

Since a large percentage of Lake Lemon users come from outside the watershed (see Section 2.10 Recreational Use), both user groups should be considered in any restoration program.

2.9 PUBLIC ACCESS AND TRANSPORTATION

Public transportation to the Lake Lemon area is limited. State Route 45 is the major road through the Lake Lemon watershed. Bloomington Transit busses travel along SR 45, but only as far as Eastern Heights, which is at least ten km from the lake. The only other public transportation available is taxi service from Bloomington, which is approximately a $12.00 one-way fare from downtown Bloomington. The majority of Lake Lemon visitors travel by private automobile, bicycle, recreational vehicle, or church/organization bus.

There are no free public boat launching facilities on Lake Lemon. Boats may be launched for a fee at Riddle Point (A City of Bloomington park) or at two marinas on the lake. Public fishing access is available along the South Shore Drive causeway on the southern shore, along the Shuffle Creek embayment and adjacent causeway, and at the spillway. None of the undeveloped areas of public access have more than just a few off-road parking spaces.

2.10 RECREATIONAL USE

Although Lake Lemon is owned by the City of Bloomington, its use as a recreational area spans many counties. It is estimated that 35-45% of the 10,000-15,000 seasonal visitors to Lake Lemon come from outside of Monroe County, some from as far away as Richmond, Indiana on a regular basis (Jim Ratliffe, personal communication). Major lake uses include fishing, swimming, and boating.

The recreational season at Riddle Point, the city-run park on Lake Lemon, extends from Memorial Day to Labor Day (camping from April 15-October 15). An entrance fee of $1.00/person is charged to use the park's facilities, which include a beach, bath house, picnic shelter, open fields, and picnic tables. A fee is also charged to launch a boat from Riddle Point. Daily fees are $3.00 for a non-motorized boat and $6.00 for a motor boat. A seasonal launch permit is also available for $20.00 (non-motorized) or $40.00 (motorized). Lakeshore property owners are assessed a $100.00 annual frontage fee which is used for lake improvements.

Winter use of Lake Lemon is discouraged due to seasonally unstable ice, although nearby residents often snowmobile and ice-fish on the lake.

2.11 MAJOR LAKES WITHIN AN 80 KILOMETER RADIUS OF LAKE LEMON

There are a number of lakes within an 80 km radius of Lake Lemon that are suitable for aquatic-based recreation. The largest of these is Lake Monroe, a 4,352 ha reservoir, located 22.5 km to the south in Monroe County. Since its construction in 1964, Lake Monroe has attracted many visitors away from Lake Lemon. Lake Monroe tends to attract a larger crowd, mostly because it has been advertised nationwide as southern Indiana's largest resort area.

Other lakes in the area offer a more similar recreational environment to Lake Lemon. Table 2-10 presents physical and chemical data for major lakes (>40 ha) within an 80 km radius of Lake Lemon. The data represent a single sample from each lake collected over the period from June to September during a five-year study of Indiana lakes (Torke and Senft 1979). Table 2-11 briefly summarizes the recreational opportunities at these same lakes.

TABLE 2-10. PHYSICAL AND CHEMICAL PARAMETERS FOR INDIANA LAKES OVER 40 HECTARES WITHIN AN 80-km RADIUS OF LAKE LEMON

Lake	Distance (km) and Direction From Lake Lemon	Size (ha)	Max. Depth (m)	Mean Depth (m)	Total P (mg/l)	Secchi Disc (m)	Eutrophication index[a]
Lemon	-	668.0	8.53	2.90	0.50/0.04	1.22/0.91	42/37
Yellowwood (Brown Co.)	9.5 S	53.8	9.14	4.33	0.04	4.33	10
Griffey Res. (Monroe Co.)	18.5 SW	52.6	9.14	3.05	0.04	2.29	40
Monroe Res. (Monroe Co.)	22.5 S	4352.2	11.58	-	0.03	3.66	25
Starve Hollow (Jackson CO.)	57 SSE	58.7	5.18	2.07	0.03	-	58
Eagle Cr. Res. (Marion Co.)	64 N	607.3	-	3.81	0.10[b]	1.22[b]	38[b]
Boggs Creek (Martin Co.)	74 SW	242.9	-	3.81	0.04	0.91	45
Brush Cr. Res. (Jennings Co.)	79.5 ESE	67.6	9.75	3.05	0.07	1.22	55
Geist Res. (Marion Co.)	79.5 NE	728.7	6.71	3.66	0.14/0.06	0.76	35

[a]Index developed by Indiana State Board of Health based on physical/chemical parameters - scores range from 0-75, oligotrophic to eutrophic.

[b]three numbers listed - middle one chosen.
From Torke and Senft (1979).

TABLE 2-11. RECREATIONAL ACTIVITIES AT MAJOR LAKES WITHIN AN 80 km RADIUS OF LAKE LEMON

Lake	Boating	Boat Launching	Fishing	Swimming
Boggs Creek	X	X	X	X
Brush Ck. Res.	X	X	X	NO
Eagle Ck Res.	X	X	X	X
Geist Res.	X	X	X	X[2]
Griffey Res.	X[1]	X	X	NO
Monroe Res.	X	X	X	X
Starve Hollow	X	X	X	X
Yellowwood	X	X	X	NO

[1]electric motors only; boat must be approved by Bloomington Department of Parks and Recreation

[2]ungraded beach.

CHAPTER 3: HISTORICAL DATA

3.1 WATER QUALITY

3.1.1 Data Availability

The City of Bloomington has collected water quality data from a number of locations in Lake Lemon and from streams draining into the lake. The approximate location of these sampling sites is given in Figure 3-1.

Plum Creek, Bear Creek, Beanblossom Creek, Rapid Creek, and Shuffle Creek were sampled during the period of 1974 - 1979 for various water quality parameters including: water temperature, pH, turbidity, dissolved oxygen, fecal coliform bacteria, nitrate, and ortho-phosphate. These same parameters were completed for water samples routinely collected at three sampling locations in Lake Lemon -- Reed Point, Riddle Point, and the Spillway -- and occasionally collected at the Lake Lemon dam.

Only a few vertical profile samples were completed by the City's staff and, as such, the data reported herein are for water samples collected just below the lake's surface.

It should be noted that the City's sampling sites for Plum Creek, Bear Creek, and Shuffle Creek were located close to the lake and may have been affected by backwater from the lake. Also, nearly all of the samples for both stream and lake sites were collected during the recreational season -- May to October.

3.1.2 Results

Water quality data for ortho-phosphate, nitrate, and fecal coliform bacteria were evaluated due to their relevance to this investigation. These data are described in subsequent sections.

Stream Sampling Sites

Fecal Coliform Bacteria. Historical fecal coliform bacteria data

CITY OF BLOOMINGTON WATER SAMPLING SITES

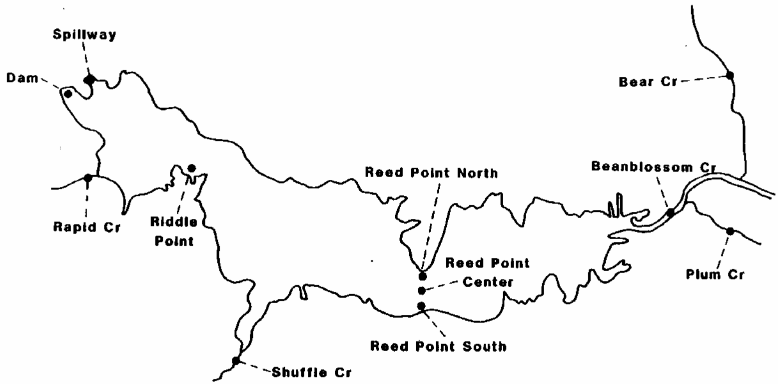


Figure 3-1. Water quality sampling sites used historically by the City of Bloomington.

for the five stream sampling sites are shown in Figure 3-2 and Tables 3-1 and 3-2. Figure 3-2 is a distribution diagram showing the percentage of sample analyses that had concentrations equal to or less than the stated concentration. As shown, Beanblossom Creek and Bear Creek have almost identical distribution curves, whereas curves for Plum Creek, Rapid Creek, and Shuffle Creek are progressively shifted to the right of those for Bear and Beanblossom Creeks. This indicates that Shuffle Creek usually has the lowest levels of fecal coliform bacteria, whereas Bear and Beanblossom Creeks have the highest levels.

Statistical information for the five stream sites is listed in Table 3-1 and was read directly from Figure 3-2. The median values were highest for Bear Creek (73 colonies/100 ml) and Beanblossom Creek (65 colonies/100 ml). The Indiana State Board of Health has established a full-body recreational standard for fecal coliform bacteria of 400 colonies/100 ml (single grab sample). Data given in Table 3-1 for the plus-one-standard deviation (+1 S.D.) include roughly 84 percent of the data points. With the exception of Bear Creek, all of the stream sites at this level of deviation had fecal coliform levels below the state's recreational standard. Both Table 3-1 and Figure 3-2 show that this standard is occasionally exceeded at all five stream sampling sites. Table 3-2 gives a further interpretation of the fecal coliform violations which took place during the period 1974 - 1979. (The reader is cautioned that Table 3-2 does not include data for the 1980 calendar year and is therefore not directly comparable to Figure 3-1 and Table 3-1.) The relatively higher incidence in fecal coliform violations at Beanblossom Creek and Bear Creek is clearly evident from this table.

Ortho-phosphate. Distribution curves for ortho-phosphate are shown in Figure 3-3 and relevant statistics are listed in Table 3-3. It is noteworthy that all five sampling sites have similar distribution curves except at high duration frequencies ($\geq$90 percent) where Beanblossom Creek and Bear Creek have considerably higher concentrations. In general, Plum Creek and Rapid Creek had slightly lower levels of ortho-phosphate at most durations.

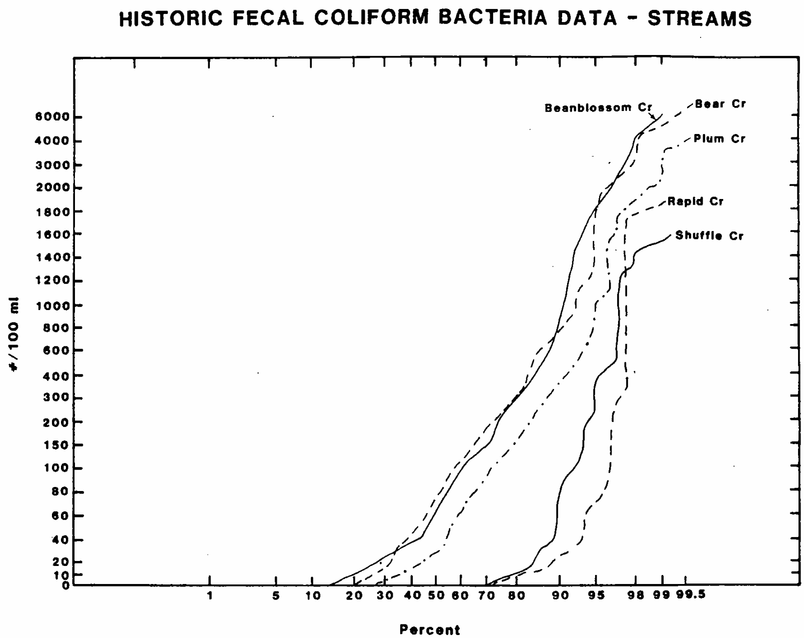


Figure 3-2. Historical fecal coliform data for Lake Lemon streams showing percent of time concentrations were equal to or lower than the stated value.

TABLE 3-1. STATISTICAL INFORMATION OF FECAL COLIFORM BACTERIA LEVELS AT SELECTED SAMPLING SITES IN LAKE LEMON WATERSHED FOR THE PERIOD 1974 -1980

Sample Site	Number of Analysis	Concentration, Colonies/100 ml				
		-2 SD[1]	-1 SD	Median	+1 SD	+2 SD
Plum Creek	193	0	0	30	225	1,900
Beanblossom Creek	200	0	5	65	375	3,500
Bear Creek	190	0	0	73	500	2,750
Shuffle Creek	88	0	0	0	25	1,300
Rapid Creek	75	0	0	0	8	1,750

[1]SD = standard deviation

TABLE 3-2. SUMMARY OF FECAL COLIFORM BACTERIA ANALYSES FOR THE PERIOD 1974 - 1979

Station/Creek	Number of Analyses	Number of Violations[1]	Percentage of Samples with Violations	Range of Violations (colonies/100ml)
Rapid Creek	64	0	0	-
Shuffle Creek	72	3	4.2	424 - 1,500
Plum Creek	181	15	8.3	420 - 3,820
Bear Creek	178	29	16.3	480 - 6,760
Beanblossom Creek	182	28	15.4	420 - 17,720

[1]in excess of 400 colonies/100 ml

TABLE 3-3. STATISTICAL INFORMATION OF ORTHO-PHOSPHATE LEVELS AT SELECTED SAMPLING SITES IN LAKE LEMON WATERSHED FOR THE PERIOD 1974 - 1979

Sampling Site	Number of Analyses	Concentration, mg/l				
		-2 SD	-1 SD	Median	+1 SD	+2 SD
Rapid Creek	68	0.000	0.014	0.037	0.122	0.233
Shuffle Creek	76	0.000	0.013	0.043	0.126	0.275
Plum Creek	171	0.000	0.015	0.037	0.090	0.230
Beanblossom Creek	173	0.004	0.020	0.050	0.128	0.420
Bear Creek	168	0.003	0.015	0.045	0.118	0.346

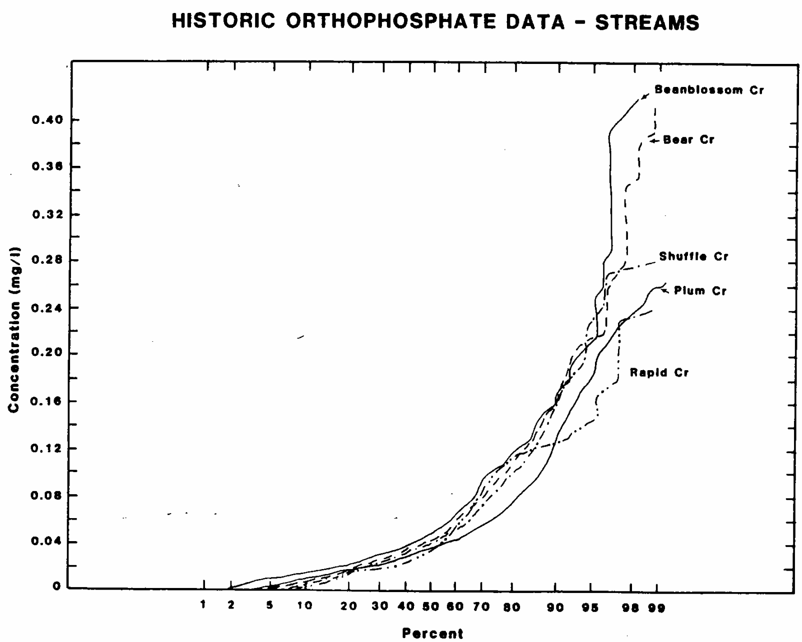


Figure 3-3. HISTORICAL ORTHOPHOSPHATE DATA FOR LAKE LEMON STREAMS SHOWING PERCENT OF TIME CONCENTRATIONS WERE EQUAL TO OR LESS THAN THE STATED VALUE.

Median phosphate levels for the five streams varied only slightly between 0.037 - 0.050 mg/l as PO_4 (Table 3-3). This corresponds to a range of 0.012 - 0.016 mg/l as P. Table 3-3 also shows a range of 0.090 - 0.128 mg/l for ortho-phosphate (as PO_4) at the plus-one-standard deviation. This indicates that only about 16 percent of the samples had ortho-phosphate levels in excess of this range.

Nitrate-nitrogen. Nitrate analyses were also completed on water samples collected at the five stream sampling sites. Figure 3-4 presents distribution curves for this parameter whereas a statistical summary is given in Table 3-4. Shuffle Creek, Rapid Creek and Plum Creek appear to have the lowest levels of nitrate at nearly all durations. It is noteworthy that all five stations have nitrate levels less than 2.5 mg/l (as nitrate) which is far below EPA's and ISBH's drinking water standard for this compound (10 mg/l as N). Table 3-4 shows that the median level of nitrate for the five stations was very low and falls in the 0.08 - 0.18 mg/l range (as NO_3).

Lake Sampling Sites

Fecal Coliform Bacteria. Analyses of fecal coliform bacteria were completed at four locations on Lake Lemon as shown in Figure 3-1. Distribution curves and statistical information for this water quality parameter are given in Figure 3-5 and Table 3-5, respectively. ISBH's 400 colonies per 100 ml body contact standard is applicable at these sampling sites. Levels of fecal coliform bacteria were rarely in excess of this standard. The exceedance rate was between two - three percent for Reed Point, Riddle Point, and near the Spillway. In contrast, samples collected near the dam site showed an exceedance rate of about five percent. The reason for the slightly higher rate of exceedance at this site is unknown.

Ortho-phosphate. Figure 3-6 and Table 3-6 depict ortho-phosphate levels at three different sampling sites near Reed Point (Figure 3-1). These three sites are called "north", "center", and "south" to reflect their relative locations off of Reed Point.

TABLE 3-4. STATISTICAL INFORMATION OF NITRATE LEVELS AT SELECTED SAMPLING SITES IN LAKE LEMON WATERSHED FOR THE PERIOD 1974 - 1979

Sampling Site	Number of Analyses	Concentration, mg/l -2 SD	-1 SD	Median	+1 SD	+2 SD
Rapid Creek	65	0.00	0.00	0.10	0.43	1.20
Shuffle Creek	68	0.00	0.00	0.08	0.33	1.35
Plum Creek	139	0.00	0.00	0.13	0.53	1.28
Beanblossom Creek	144	0.00	0.01	0.18	0.65	1.70
Bear Creek	141	0.00	0.00	0.18	0.65	2.04

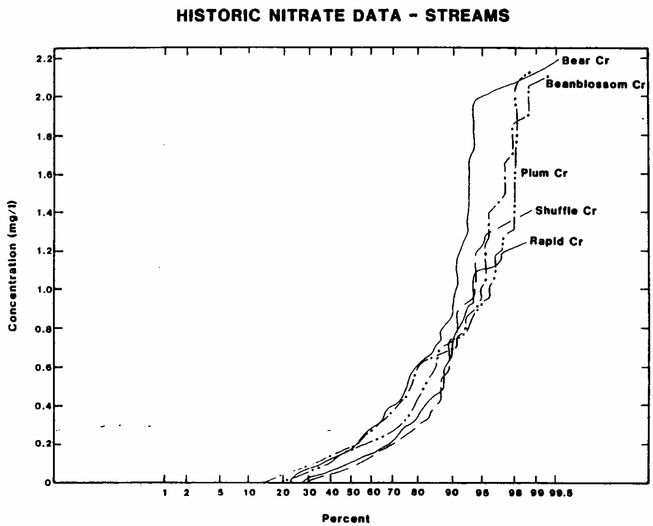


Figure 3-4. Historical nitrate data for Lake Lemon streams showing percent of time concentrations were equal to or less than the stated values.

TABLE 3-5. STATISTICAL INFORMATION OF FECAL COLIFORM BACTERIA AT SELECTED SAMPLING SITES IN LAKE LEMON WATERSHED FOR THE PERIOD 1974 - 1979

Sampling Site	Number of Analyses	Concentration, Colonies/100 ml -2 SD	-1 SD	Median	+1 SD	+2 SD
Reed Point	99	0	0	0	20	775
Riddle Point	84	0	0	0	8	125-500a
Dam	78	0	0	0	33	920
Spillway	240	0	0	2	43	375

[1]range of concentration at this level of variability about the mean.

HISTORIC FECAL COLIFORM BACTERIA DATA - LAKE

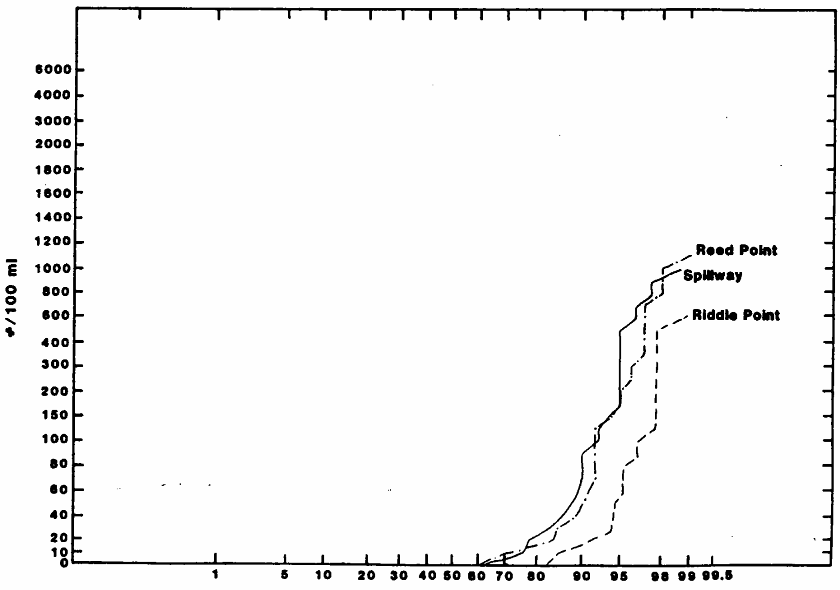


Figure 3-5. Historical fecal coliform bacteria data for Lake Lemon showing percent of time concentrations were equal to or less than the stated values.

TABLE 3-6. SUMMARY OF ORTHO-PHOSPHATE ANALYSES FOR REED POINT, 1974 - 1976

Sampling Site	Number of Analyses	Concentration, mg/l -2 SD	-1 SD	Median	+ 1 SD	+ 2 SD
North	66	0.01	0.01	0.03	0.12	0.19
Center	64	0.01	0.01	0.03	0.10	0.20
South	73	0.01	0.01	0.04	0.11	0.22
All Three Sites Combined	203	0.01	0.01	0.03	0.11	0.20

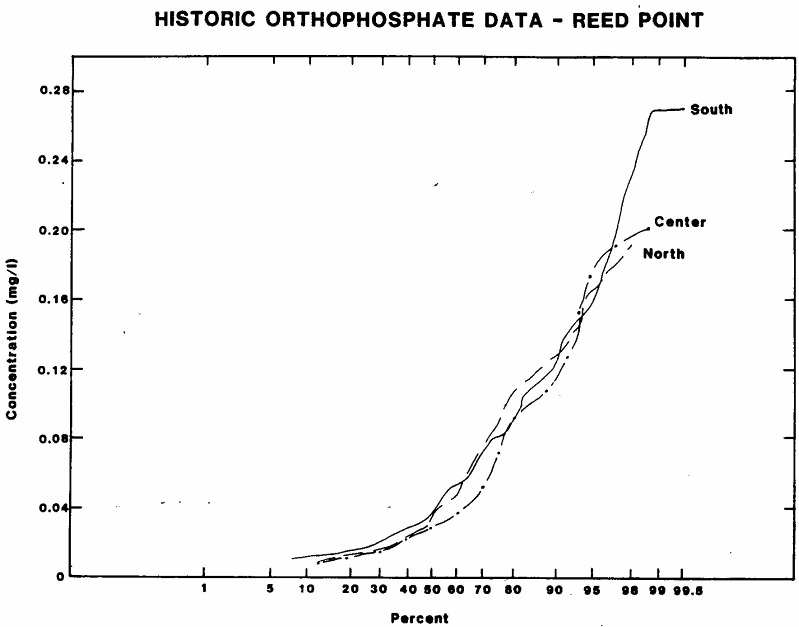


Figure 3-6. Historic orthophosphate data for Reed Point showing percent of time concentrations were equal to or less than the stated values.

Two observations are evident from the data. First, ortho-phosphate levels are low, with a median ranging between 0.03 - 0.04 mg/l (as PO_4). Second, there is little difference between reported concentrations at the three sampling sites. This later observation is clearly evident in Figure 3-6 where the distribution curves trace nearly the same line over most of the frequencies of occurrence.

Ortho-phosphate levels at two other locations in Lake Lemon (Spillway and Riddle Point) are depicted in Figure 3-7 along with the data for Reed Point. Riddle and Reed Points have almost identical distribution curves, whereas the duration curve for the Spillway sampling site is offset to the left. This indicates that higher levels of ortho-phosphate occur at the Spillway site in comparison to those recorded at Reed and Riddle Points. This observation is also evident from the statistical data shown in Table 3-7.

It is also noteworthy to mention that ortho-phosphate levels are usually fairly low. For example, the median concentration ranged 0.033 - 0.062 mg/l (as PO_4) for the three sampling sites. This corresponds to a range of 0.011 - 0.020 mg/l when reported as P. The plus-one standard deviation values (Table 3-7) ranged between 0.092 - 0.175 mg/l as PO_4 or between 0.030 - 0.057 mg/l when reported as P.

Nitrate-nitrogen. In-lake nitrate levels are depicted in Figure 3-8 and summarized in Table 3-8. All analyses were below 2.5 mg/l as NO_3. The range of the median concentration for the three sites (Table 3-8) was 0.08 - 0.15 mg/l as NO_3, while a range of 0.31 - 0.63 mg/l as NO_3 was calculated for the plus-one standard deviation. The Spillway sampling site had the highest levels of nitrate at any selected duration, with intermediate values at Reed Point, and the lowest values at Riddle Point. The reason for the slightly higher levels of nitrate (and phosphate) in the most western lobe of Lake Lemon near the spillway is unknown.

3.2 FISHERIES/BIOLOGICAL

3.2.1 Historical Data for the Lake Lemon Fishery

The Department of Conservation (predecessor of the Department of

TABLE 3-7. STATISTICAL INFORMATION ON ORTHO-PHOSPHATE LEVELS AT SELECTED SAMPLING SITES IN LAKE LEMON FOR THE PERIOD 1974 - 1979.

Sampling Site	Number of Analyses	Concentration, mg/l				
		-2 SD	-1 SD	Median	+1 SD	+2 SD
Spillway	217	0.000	0.018	0.062	0.175	0.450
Riddle Point	207	0.000	0.010	0.036	0.092	0.250
Reed Point	203	0.005	0.013	0.033	0.110	0.198

HISTORIC ORTHOPHOSPHATE DATA - LAKE

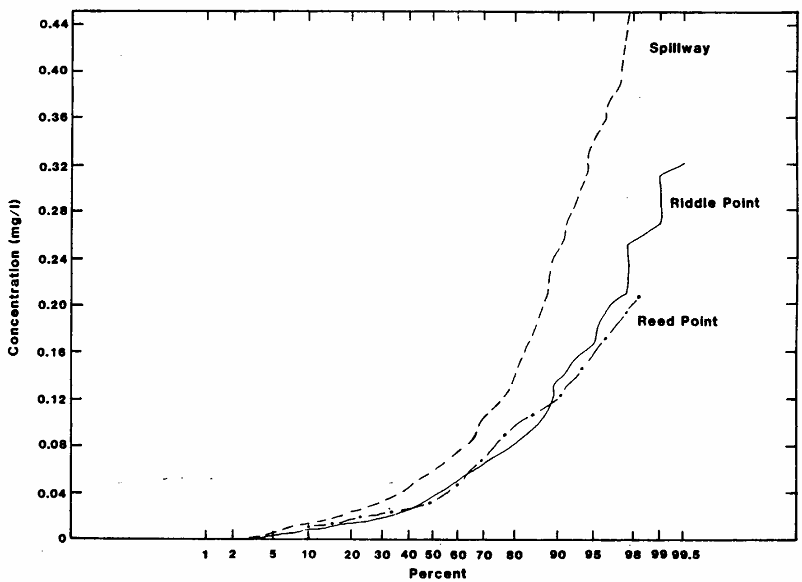


Figure 3-7. Historical orthophosphate data for Lake Lemon showing percent of time concentrations were equal to or less than the stated value.

TABLE 3-8. STATISTICAL INFORMATION ON NITRATE LEVELS AT SELECTED SAMPLING SITES IN LAKE LEMON FOR THE PERIOD 1974 - 1979.

Sampling Site	Number of Analyses	Concentration, mg/l				
		-2 SD	-1 SD	Median	+1 SD	+2 SD
Spillway	164	0.00	0.00	0.15	0.63	1.97
Riddle Point	165	0.00	0.00	0.08	0.31	1.65
Reed Point	191	0.00	0.00	0.08	0.42	1.36

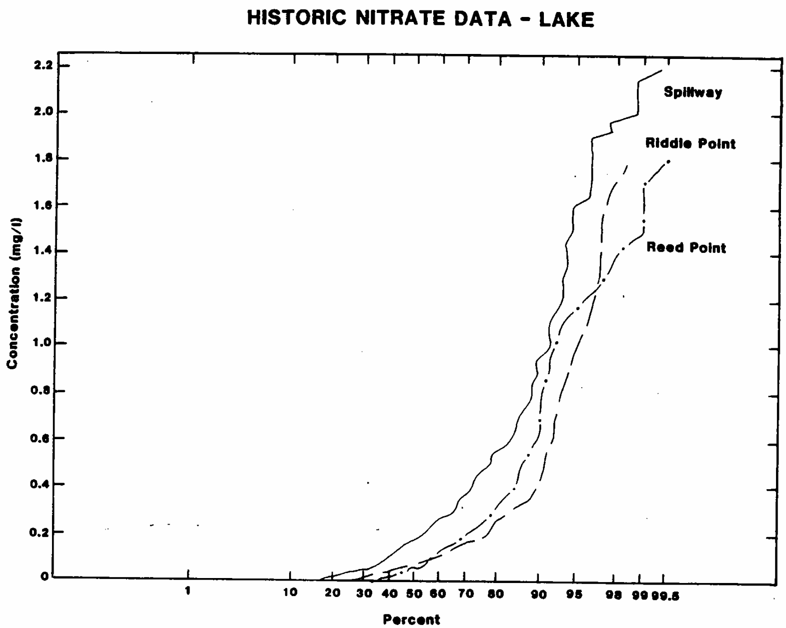


Figure 3-8. Historical nitrate data for Lake Lemon showing percent of time concentrations were equal to or less than the stated value.

Natural Resources) began a fish survey of Lake Lemon shortly after the lake was filled but it was never completed. Some stocking of the lake was also done at that time. The Department of Natural Resources, however, has no records of these activities, nor had they done any work historically on the lake themselves prior to 1982. Data for this report were, therefore, collected from interviews with people who have had prolonged and regular contact with the Lake Lemon fishery. Bait and tackle shop personnel, anglers living near the lake, and the lake manager were consulted.

Prior to the construction of the lake, the Beanblossom Creek fishery was very productive. The stream system included at least the following species:

Largemouth Bass	-	_Micropterus salmoides_
Smallmouth Bass	-	_Micropterus dolomieiu_
Rock Bass	-	_Ambloplates rupestris_
Bluegill	-	_Lepomis macrochirus_
Longear Sunfish	-	_Lepomis megalotis_
Blue Catfish	-	_Ictalurus furcatus_
Channel Catfish	-	_Ictalurus punctatus_
Yellow Bullhead	-	_Ictalurus natalis_
White Sucker	-	_Catostomus commersoni_
Carp	-	_Cyprinus carpio_

Other species which were probably indigenous to the stream system are the following:

Carpsucker or "Silver Carp"	-	_Carpiodes carpio_
Bowfin or "Dogfish"	-	_Amia calva_
Northern Pike	-	_Esox lucius_
Black Crappie	-	_Pomoxis nigromaculatus_

an unidentified species of lamprey (Petromyzonidae)

All the fishes listed above exist now in both Lake Lemon and the stream system feeding it, although the silver carp seems to prefer the lotic environment.

Listed below are fishes which can be found in the lake but were probably introduced by the public into the system:

Flathead Catfish	-	_Pylodictis olivaris_

Walleye	- _Stizostedion vitreum_
Yellow Perch	- _Perca flavescens_
Striped Bass	- _Morone saxatilis_
Yellow Bass	- _Morone mississippiensis_
Hickory Shad	- _Alosa mediocris_

The presence of walleye in Lake Lemon was the result of one resident with several buckets of fingerlings. The striped bass were not intentionally stocked into Lake Lemon. They were stocked upstream, into a private lake. The dam of this lake gave out, allowing this fish access to Lake Lemon. The other three species are of unknown origin. Table 3-9 summarizes the origin and status of Lake Lemon's fishery.

3.2.2 Trends In the Fishery's Yield

Largemouth bass fishing is said to be on the increase in recent years in terms of both numbers and size. Some of the weights reported by local fishermen include 8.5 lbs, nine lbs, and 9.2 lbs. Most bass anglers believe that the presence of _Myriophyllum_ is beneficial to their sport and would not like to see this macrophyte removed.

Larger numbers of bluegill and longear sunfish are being caught now than in the past. However the size of these fish would indicate a stunted population. This is also true of the yellow perch, although large numbers of this fish are not being caught. The crappie fishing is said to be good with 2 - 3.5 lb fish being reported.

Catfish fishing is said to be the best ever. A 38 lb. flathead was reported in 1982. The number of bullheads, however, has decreased, although they are frequently found in the stomachs of the larger catfish.

3.2.3 Public Perceptions of Fisheries Problems in Lake Lemon

1. Fisherman have said that crappie reductions seem to follow the chemical control of the macrophytes. Clearly more details are necessary to draw conclusions from this observation.

TABLE 3-9. SUMMARY OF THE ORIGIN AND CURRENT STATUS OF LAKE LEMON'S FISHERY[1]

Family	Species	Probably Indigenous	Probably Introduced	Frequency of large fish increasing	Stunted Population	# of fish caught increasing	# of fish caught decreasing
Centrarchidae	Largemouth Bass	X		X		X	
	Smallmouth Bass	X					
	Rock Bass	X					
	Bluegill	X			X	X	
	Longear Sunfish	X			X	X	
	Black Crappie	X		X			
Percidae	Walleye		X				
	Yellow Perch		X		X		
Percichthyidae	Striped Bass		X				
	Yellow Bass		X				
Esocidae	Northern Pike	X					
Ictaluridae	Blue Catfish	X		X		X	
	Channel Catfish	X		X		X	
	Flathead Catfish		X	X		X	
	Yellow Bullhead	X					X
Catostomidae	Carpsucker	X					
	White Sucker	X					
Cyprinidae	Carp	X[2]				X	
Clupeidae	Hickory Shad		X				
Amiidae	Bowfin	X					
Petromyzontidae	Unidentified lamprey	X					

[1]Gathered largely from personal accounts of local experts.
[2]Although considered an exotic species, it was well established in the local streams long before the lake was constructed.

2. The lake contains too many rough fish.

3. Sedimentation and turbidity restrict fishing.

3.3 HISTORICAL STREAMFLOW RECORDS

The U.S. Geological Survey, Water Resources Division, Indianapolis, Indiana, has operated four gaging stations in the Beanblossom Creek watershed. Table 3-10 lists these gaging stations. The only gaging station still in operation is Beanblossom Creek at Beanblossom, Site 03354500. This site is located in the headwaters of Beanblossom Creek and is about seven river miles upstream of Lake Lemon. Streamflow records gathered at this site by the U.S. Geological Survey in the 1982 water year were used in conjunction with partial-record site measurements made by the research staff throughout the Beanblossom Creek watershed to ascertain the spatial distribution of surface runoff in the watershed (see Section 4.2).

TABLE 3-10. U.S. GEOLOGICAL SURVEY GAGING STATIONS IN THE BEANBLOSSOM CREEK WATERSHED

Station Name	Station Number	Drainage Area (mi^2)	Period of Record	Current Status
Bear Creek near Trevlac (Brown Co.)	03355000	6.9	1952-73	Discontinued, now Partial Record Site
Beanblossom Creek at Beanblossom (Brown Co.)	03354500	14.6	1951-present	In Operation
Lake Lemon near Bloomington, IN (Monroe Co.)	03355400	70.9	1953-58, 1960-78	Discontinued
Beanblossom Creek at Dolan (Monroe Co.)	033556000	100.0	1946-78	Discontinued

Bear Creek near Trevlac drains a small watershed directly north of Lake Lemon and was gaged by the U.S. Geological Survey from 1952-73. The station was converted to a partial-record site in 1973 to collect additional flood information. The Beanblossom Creek at Dolan gaging station was operated from 1946-78 and was discontinued in 1978. This historical gaging site was located about seven river miles below the Lake Lemon dam site.

The U.S. Geological Survey has also operated a gage at the dam site at Lake Lemon (03355400). Lake elevations were recorded during the periods 1953-58 and 1960-78, from which lake elevation, storage content, and change in storage were calculated for Lake Lemon on a monthly basis. Facilities are also available at the dam site to record the amount of water released through the outlet works. However, a systematic record-keeping program for the amount of water released from Lake Lemon has not been attempted.

Flow duration curves for the three stream gaging stations listed in Table 3-10 are shown in Figure 3-9. These curves illustrate the percentage of time when the recorded streamflow was equal to or greater than selected streamflow values. Data for the Dolan gage have been separated into the period before and the period after Lake Lemon was constructed to illustrate the influence of regulation from this lake. It is noteworthy that the slopes of the duration curves at all three gages are very similar under non-regulated conditions. Table 3-11 summarizes selected statistics from Figure 3-9.

The streamflow statistics shown in Figure 3-9 and listed in Table 3-11 illustrate that Beanblossom Creek and its tributaries receive little sustained contribution of streamflow from groundwater. This is typical of smaller streams in Indiana which normally do not penetrate aquifers of significant yield. Figure 3-9 illustrates that both Beanblossom Creek at Beanblossom and Bear Creek at Trevlac have recorded streamflows less than 0.01 ft^3/sec during a significant portion of the time. Typically, near zero or zero flow conditions occur during the months of June-November, after spring runoff has receded.

The low flow characteristics of Beanblossom Creek and one of its tributaries (Bear Creek) is further illustrated in Tables 3-12 and 3-13. Table 3-12 shows the number of days in each water year when

TABLE 3-11. STREAMFLOW DURATION STATISTICS FOR GAGING STATIONS IN THE BEANBLOSSOM CREEK WATERSHED

U.S.G.S. Stream Gaging Station	Streamflow Statistics							
	50% Duration		80% Duration		90% Duration		99% Duration	
	ft^3/sec	$ft^3/sec/mi^2$	ft^3/sec	$ft^3/sec/mi^2$	ft^3/sec	$ft^3/sec/mi^2$	ft^3/sec	$ft^3/sec/mi^2$
Bear Creek at Trevlac	1.2	0.17	0.1	0.014	0.01	0.0014	0	-
Beanblossom Creek at Beanblossom	3.0	0.21	0.2	0.014	0.01	0.0007	0	-
Beanblossom Creek at Dolan[1]	36.0	0.36	4.4	0.044	1.9	0.019	0.2	0.002

[1] prior to regulation, 1947-51

the streamflow was reported as zero by the U.S. Geological Survey. Beanblossom Creek at Beanblossom and Bear Creek at Trevlac usually have no flows for many days each year. This can be seen more quantitatively in Table 3-13 which lists the number of days when the reported streamflow was less than or equal to three arbitrarily selected low flows (0.00, 0.1 and 1.0 ft^3/sec). As shown, the headwaters of Beanblossom Creek and Bear Creek had reported streamflows less than 0.1 ft^3/sec 20 and 16 percent of the time respectively, again illustrating the poor groundwater contribution to streamflow. Low-flow characteristics for Beanblossom Creek at Dolan are higher, reflecting the larger drainage area for this site. However, the contribution to surface runoff from groundwater is small to negligable in comparison to runoff occuring from precipitation, snow melt, and water releases from Lake Lemon.

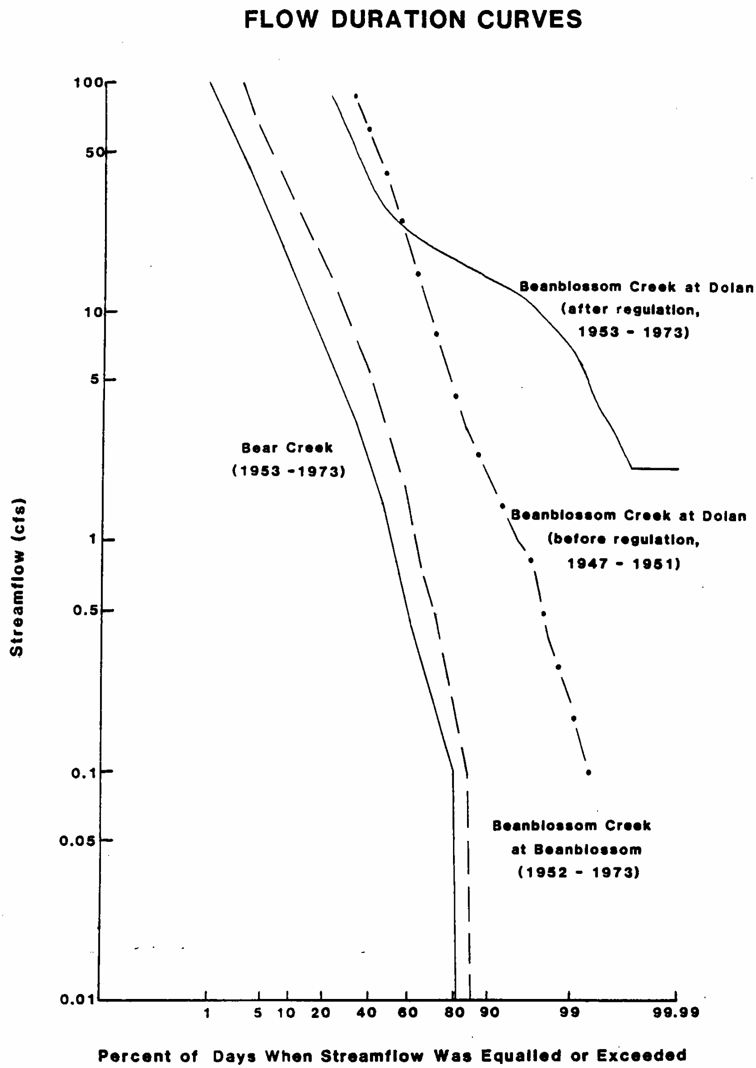


Figure 3-9. Flow duration curves for Beanblossom and Bear Creeks.

TABLE 3-12. NUMBER OF DAYS WHERE A ZERO AVERAGE DAILY STREAMFLOW WAS REPORTED BY THE U.S. GEOLOGICAL SURVEY

Water Year	Beanblossom Creek at Beanblossom	Bear Creek at Trevlac	Beanblossom Creek at Dolan	Remarks
1946	-	-	-	Before Lake Lemon was constructed
47	-	-	1	
48	-	-	6	
49	-	-	3	
1950	-	-	0	
51	-	-	0	After Lake Lemon was constructed
52	66	-	0	
53	111	122	0	
54	171	187	0	
55	96	100	0	
56	34	80	0	
57	64	99	0	
58	15	24	0	
59	24	70	0	
1960	36	42	0	
61	77	100	0	
62	45	20	0	
63	38	62	0	
64	167	154	0	
65	89	110	0	
66	46	77	0	
67	30	68	0	
68	16	26	0	
69	0	0	0	
1970	0	12	0	
71	2	12	0	
72	44	23	0	
73	0	0	0	
74	1	-	0	
75	29	-	0	
76	42	-	0	
77	12	-	0	
78	3	-	0	
79	0	-	-	
1980	0	-	-	

TABLE 3-13. SELECTED STREAMFLOW STATISTICS FOR STREAM GAGING STATIONS IN THE BEANBLOSSOM CREEK WATERSHED ILLUSTRATING LOW-FLOW CHARACTERISTICS

USGS Stream Gaging Station	Period of Record	Total Number of Days of Record	Number of Days When Reported Streamflow was:[1]		
			0.00 ft^3/sec	$\leq$ 0.1 ft^3/sec	$\leq$ 1.0 ft^3/sec
Bear Creek at Trevlac	1953-73	7,670	1388 (18.1%)	1543 (20.1%)	3628 (47.3%)
Beanblossom Creek at Beanblossom	1952-73	8,036	1171 (14.6%)	1274 (15.9%)	2890 (36%)
Beanblossom Creek at Dolan (Before Regulation)	1947-50	1,826	10 (0.1%)	18 (0.5%)	101 (5.5%)
Beanblossom Creek at Dolan (After Regulation)	1951-73	7,035	0 (0%)	0 (0%)	0 (0%)

1 number in parentheses reflects the percentage of daily streamflows with a reported value less than or equal to the streamflow stated at the top of the column.

CHAPTER 4: DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 INTRODUCTION

The collection of current data during the project period was extensive. Water quality samples and stream discharge measurements were taken at monthly intervals from late October 1981 to May 1982, bi-weekly from May 1982 to September 1982, and monthly in September and October 1982. This represents a total of 16 sampling dates. Other data were collected as needed. These included: lake elevation, sediment chemistry, sediment depth, septic leachate survey, and a fisheries survey. The results of these analyses follow in subsequent sections.

4.2 SURFACE WATER HYDROLOGY

Upon review of the historical streamflow characteristics at three stream gaging stations in the Beanblossom Creek watershed (Section 3.3), it was evident that groundwater contributions to Lake Lemon were insignificant in comparison to surface runoff, especially during summer months when water quality conditions in Lake Lemon are of most concern. Emphasis in this project was placed, therefore, on understanding the spatial distribution of surface runoff in the Lake Lemon watershed. The outflow rate from Lake Lemon was also determined. The stream gaging program completed in the 1982 water year as part of this study proved to be valuable for: (a) interpreting water quality data collected from both stream and lake sampling stations (Section 4.3); (b) completing the water budget (balance) for Lake Lemon (Chapter 5); (c) completing the nutrient budget (balance) for Lake Lemon (Chapter 6).

The location of sites selected for stream gaging correspond to those where samples were collected for water quality determinations. Figure 4-1 shows the location of gaging sites. The station letters are as follows:

WATER SAMPLING LOCATIONS

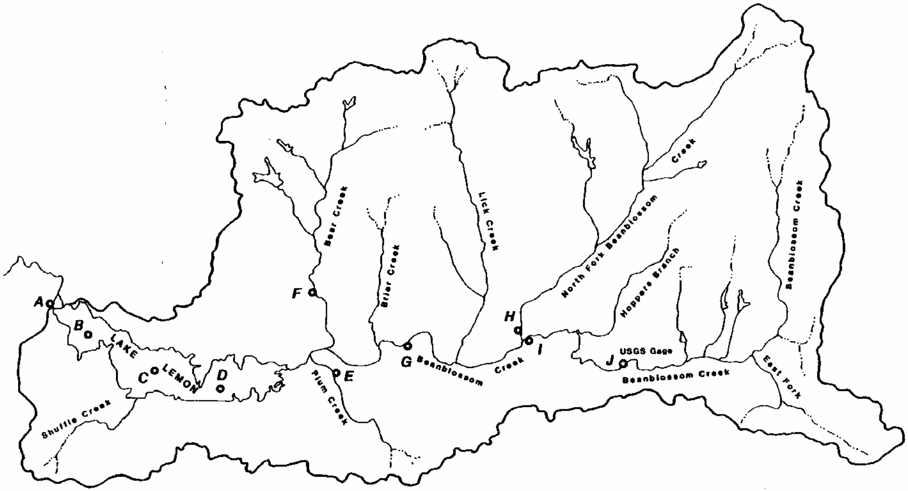


Figure 4-1. Sites where water quality and stream discharge were regularly sampled.

Station Letter	Station Name and Location
A	Beanblossom Creek about 0.4 miles below the Lake Lemon dam.
E	Plum Creek about 0.6 miles above its confluence with Beanblossom Creek, just north of the State Route 45 bridge.
F	Bear Creek about 1.4 miles above its confluence with Beanblossom Creek (discontinued USGS gage).
G	Beanblossom Creek about three miles upstream from Lake Lemon.
H	North Fork Beanblossom Creek at State Route 45 just above the confluence with Beanblossom Creek.
I	Upper Beanblossom Creek at State Route 45 just above the confluence with North Fork Beanblossom Creek.
J	Beanblossom Creek at Beanblossom, IN (USGS gage).

Streamflow measurements were made on 19 different dates during the period July, 1981 to October, 1982. On each date, the field personnel visited the USGS gaging station on Beanblossom Creek in Beanblossom, Indiana to record the gage height, from which the streamflow passing the gage was determined using this station's current rating curve. Thereafter, discharge measurements were made by wading measurements at each of the partial-record sites (A, E, F, G, H, and I) using standard equipment and procedures specified by the Water Resources Division, U.S. Geological Survey (Buchanan and Somers 1965). Table 4-1 lists the results of the discharge measurements made during this project.

Correlation graphs were prepared which relate the recorded streamflow at the Beanblossom gaging station (Site J) to the measured streamflow on the same date at the partial-record sites. Figures 4-2 to 4-4 show the correlations obtained. The U.S. Geological Survey uses correlation curves extensively to study the low-flow characteristics of streams and to transfer drought statistics from locations with a long period of record (i.e. gaging stations) to partial-record or ungaged sites. Procedures for conducting low-flow investigations have been described by the U.S.

TABLE 4-1. LISTING OF RESULTS FROM STREAMFLOW MEASUREMENTS MADE IN BEANBLOSSUM CREEK WATERSHED AS PART OF THIS PROJECT[a]

Streamflow Measurement Dates	Gaging Sites J (gage height)	J (streamflow)	A	E	F	G	H	I
7-9-81	-	0.77	-	0.220	0.088	1.83	0.268	0.987
8-7-81	-	1.4	-	-	0.55	-	1.08	3.71
10-8-81	-	0.10	-	-	1.47	-	-	-
10-28-81	-	0.94	-	0.679	0.523	2.99	0.177	1.42
12-9-81	1.29	1.25	-	0.669	0.574	3.16	0.509	1.69
1-21-82	1.39	2.89	37.2	1.08	1.18	8.71	2.55	3.62
2-24-82	1.86	19.1	111.0	5.52	12.1	56.1	16.7	25.0
3-17-82	2.20	55.9	1,000.[b]	18.5	35.7	194.0	61.9	73.7
4-14-82	1.71	13.5	84.7	5.35	8.76	38.1	10.5	18.2
5-5-82	1.42	3.60	27.1	1.17	1.98	8.63	2.70	4.41
5-19-82	1.36	2.24	9.52	0.825	0.66	5.34	1.47	2.53
6-2-82	1.88	26.4	152.0	3.17	3.78	57.0	8.93	28.8
6-17-82	1.64	11.7	15.9	0.92	1.76	17.8	8.16	16.2
6-30-82	1.72	15.2	77.4	5.67	3.95	25.2	4.23	12.0
7-21-82	1.35	2.44	15.4	0.52	1.52	5.75	0.86	2.16
8-4-82	1.21	0.36	1.75	0.26	0.15	0.56	0.13	0.17
8-18-82	1.21	0.36	4.19	0.29	0.26	0.76	0.10	0.22
9-9-82	1.27	0.769	34.9	0.49	1.00	3.50	0.90	-
10-12-82	1.26	0.769	5.6	0.20	0.26	1.68	0.20	0.34

[a] all data are expressed in ft^3/sec, except for the gage height readings for Site J (U.S.G.S. gage) which are in feet.

[b] estimated

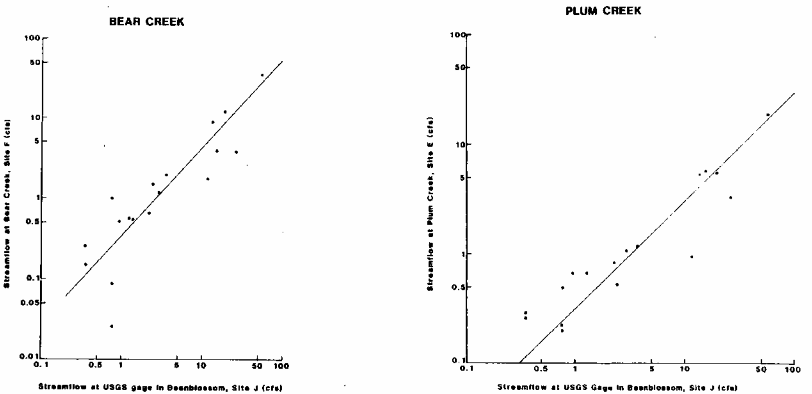
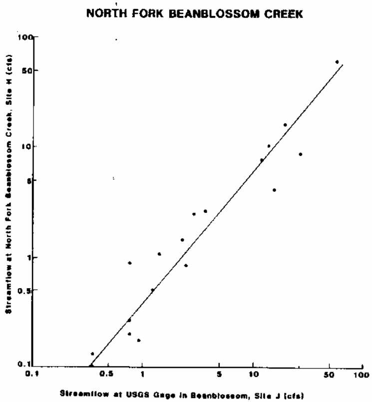


Figure 4-2. Correlations between streamflow at the USGS gage and Bear and Plum Creeks.



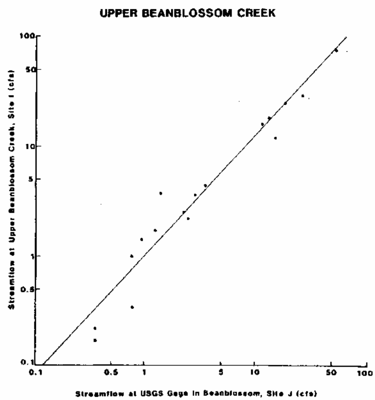


Figure 4-3. Correlations between streamflow at the USGS gage and the North Fork and Upper Beanblossom Creek.

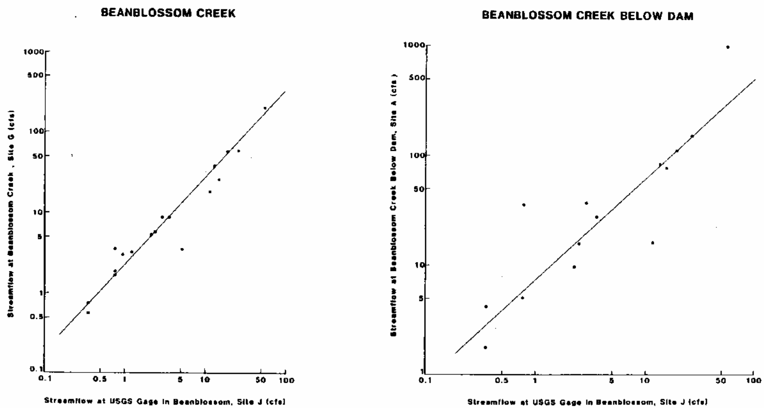


Figure 4-4. Correlations between streamflow at the USGS gage and Beanblossom Creek at Site G and below the Lake Lemon Dam.

Geological Survey (Riggs 1968) and were used without deviation in this study.

The utility of the correlation curves shown in Figures 4-2 to 4-4 is, of course, the ability to predict streamflow conditions at the partial-record sites from gage height (or streamflow) readings at the USGS gage in Beanblossom. For example, an instantaneous streamflow reading at the USGS gage of 1.0 ft^3/sec yields the following estimates of instantaneous streamflows at the partial-record sites (using the correlations given in Figures 4-2 to 4-4):

Site	Predicted Streamflow (cfs)
H	0.4
I	1.0
G	2.2
E	0.3
F	0.4
A	7.2

Also, the relationships evident in Figures 4-2 to 4-4 can be used to estimate selected flow statistics at the partial-record sites. Table 4-2 lists such statistics for the 50 and 80 percent flow durations. In summary, the correlations evident in Figure 4-2 to 4-4 provide a more complete picture of the spatial variation of streamflow in the Beanblossom Creek watershed than known previously, especially under low-flow conditions. These correlations were also used to complete the nutrient and flow budgets for Lake Lemon.

It is noteworthy to mention that the 1982 water year (October 1, 1981 - September 30, 1982) was fairly typical in terms of runoff conditions within the Beanblossom Creek watershed. This can be seen from the streamflow data for Beanblossom Creek at Beanblossom listed in Table 4-3 and Figure 4-5. With the exception of flow conditions in January, 1982 monthly streamflow data for the 1982 water year fell within $\pm$ one standard deviation range of the mean monthly streamflows (based on long-term streamflow records for the period 1952-73). As shown in Table 4-3, the high amount of runoff which occurred in January 1982 (58.7 ft^3/sec) exceeds the average

TABLE 4-2. ESTIMATED STREAMFLOW STATISTICS FOR PARTIAL-RECORD SITES IN BEANBLOSSOM CREEK WATERSHED

Gaging Site	Estimated Streamflow Statistics[b]			
	50% Duration		80% Duration	
	ft^3/sec	$ft^3/sec/mi^2$	ft^3/sec	$ft^3/sec/mi^2$
H	1.45	0.11	0.05	0.004
I	3.30	0.18	0.17	0.009
G	7.30	0.18	0.39	0.009
E	0.94	0.23	0.06	0.015
F	1.20	0.17	0.06	0.009
A	20.00	0.28	1.60	0.023

[a] Refer to Figure 4-1 for location of sites.

[b] Estimated using Figures 4-2 to 4-4 and streamflow statistics for Beanblossom Gaging Station (Q_{50} = 3.0 ft^3/sec and Q_{80} = 0.2 ft^3/sec).

TABLE 4-3. MONTHLY STREAMFLOW INFORMATION FOR THE U.S.G.S. GAGING STATION ON BEANBLOSSOM CREEK AT BEANBLOSSOM, IN (03354500)

Month	Monthly Streamflow 1982 Water Year (ft^3/sec)	Streamflow Statistics for Period of Record[1], ft^3/sec		
		mean monthly streamflow	standard deviation	mean monthly streamflow $\pm$ one stand deviation
Oct	0.97	0.85	1.14	0 - 2.0
Nov	1.3	8.0	10.0	0 - 18.0
Dec	10.2	20.1	30.0	0 - 50.1
Jan	58.7	20.4	19.7	0.7 - 40.1
Feb	38.7	24.7	17.8	6.9 - 42.5
Mar	43.5	32.5	21.2	11.3 - 53.7
Apr	24.7	33.9	19.6	14.3 - 53.5
May	8.7	25.6	25.7	0 - 51.3
Jun	15.7	12.0	16.0	0 - 28.0
Jul	4.0	7.2	11.9	0 - 19.1
Aug	1.6	1.4	2.8	0 - 4.2
Sep	1.9	1.7	3.9	0 - 5.6

1 for period 1952-73

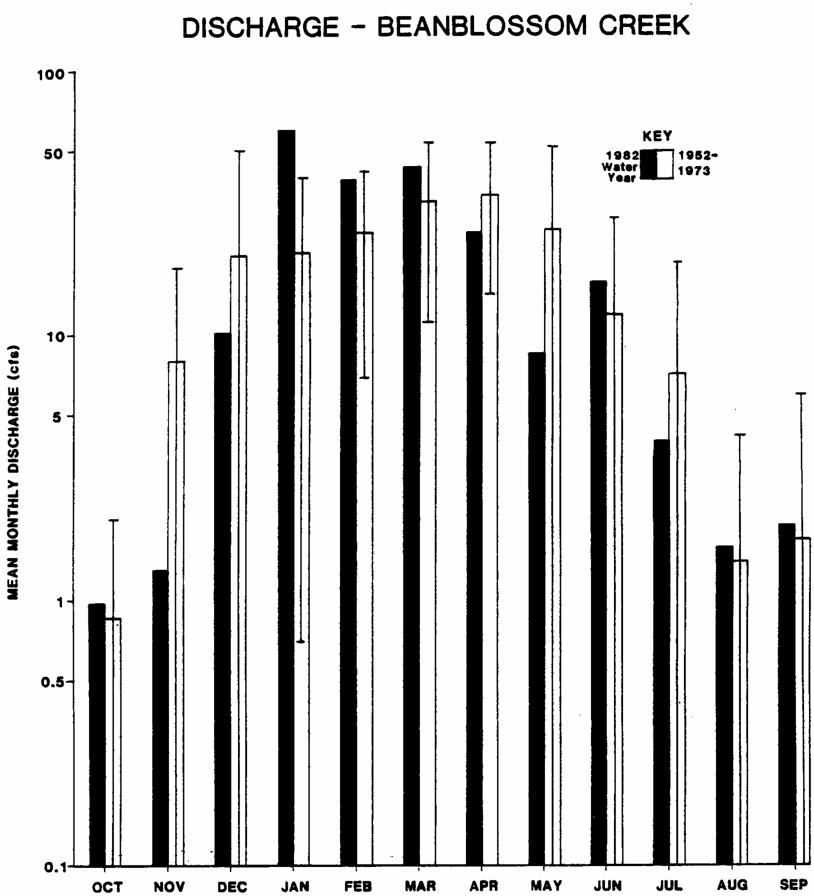


Figure 4-5. Comparison of mean monthly discharges at the USGS gage for 1982 and the preceding twenty years.

January streamflow (20.4 ft^3/sec) by a factor of about three. The high streamflow for this month was a result of higher than normal rainfall.

4.3 WATER QUALITY

4.3.1 Sampling Methods

Four sampling sites were established in Lake Lemon to collect samples for water quality and algae analyses (Figure 4-1). Three of the sites are located in the middle of each of the three basins (Sites B, C, D) and one site (Site A) is at the outlet from the lake. At Sites C and D, water samples were collected with a one liter Kemmerer sampler at three depths: just below the surface (C1, D1), middle (C2, D2) and just off the bottom (C3, D3). At Site B, because it is the deepest part of the lake, four samples were collected: just below the surface (B1), just off the bottom (B4) and two in between (B2, B3). At Site A, water was collected from the discharge pipe which draws water from the bottom of the lake. The pipe was closed from May until August and during this period water was collected from surface water immediately before it flowed over the spillway. Five sites on streams within Lake Lemon's watershed were also sampled: Site E (Plum Creek), Site F (Bear Creek), Site G (Beanblossom Creek), Site H (North Fork Beanblossom Creek), Site I (Upper Beanblossom Creek). Stream water samples were collected from just below the water's surface. All samples were collected in the morning of each sample date. Samples were analyzed for the following water quality parameters:

1) temperature
2) dissolved oxygen (DO)
3) pH
4) alkalinity
5) soluble reactive phosphorus (SRP)
6) total phosphorus (TP)
7) ammonia-nitrogen
8) nitrate-nitrogen
9) total Kjeldahl nitrogen (TKN)
10) chlorophyll _a_

11) suspended solids

12) Secchi disk transparency

13) fecal coliform bacteria

The City of Bloomington's Laboratory analyzed Lake Lemon water samples for the following parameters: SRP, total phosphorus, ammonia-nitrogen, nitrate-nitrogen, TKN, fecal coliform bacteria, and suspended solids. Temperature, DO, pH, and Secchi disk transparency were measured in situ. Alkalinity and chlorophyll a determinations were made in SPEA's laboratories. The original data for each sample date are presented in raw form in Appendix A.

Weather conditions during each of the water quality sampling trips are summarized in Table 4-4. These data are presented because they are closely related to certain lake parameters such as lake mixing, turbidity, and water temperature. The effects of weather conditions on some water quality parameters can be seen in the data.

4.3.2 Temperature and Dissolved Oxygen

Dissolved oxygen was measured in situ with a pressure compensating probe. This instrument was calibrated in the field using a standard air calibration technique. Temperature was measured in situ with a thermister thermometer on the same instrument. Water temperature results are presented in Figures 4-6 through 4-8.

Temperature data show that the lake heats up slowly following the disappearance of the ice cover in late February. It remains below 10°C through April and then heats up rapidly in May. Thereafter water temperature fluctuates during the summer months between 20 - 30 C except for Site B where the bottom temperature remains stable at around 20°C.

Site B exhibits thermal stratification from June through August (Figure 4-6) whereas Site D exhibits only temporary thermal stratification on three dates (Figure 4-7). Site D is in the shallowest end of the lake, and is more affected by turbulent mixing due to Beanblossom Creek. By the October sampling date, the lake was well mixed indicating that fall turnover had taken place. There is little variation in water temperature among the three sites (Figure 4-8).

TABLE 4-4. WEATHER CONDITIONS ON SAMPLING DATES

Date	Air Teperature (C)	Wind Speed (mph)	Cloud Cover	Water Color
10/28 B*	10	10	100%, mist	grey
12/02 L	2	0	100%, sleet	-
12/09 S	0 10	25%	-	
01/20-L	1	0-5	100%	ice cover 6-13"
01/21 S	1	0	100%, fog	some ice
02/24 S	3	0-5	100%	soft ice
03/17 L	10	5	100%	sandy tan
04/13 L	16	15-20	clear	dark green
04/14 S	16	0-5	clear	-
05/05 L	21	10-15	clear	dark khaki
05/06 S	21	0-5	clear	-
05/18 L	18	calm	25%, rain	khaki
05/19 S	20	0-5	clear	-
06/01 L	16	5-10	100%	olive, drab
06/02 S	20	calm	clear	-
06/16 L	16	0	100%, rain	khaki
06/17 S	11	0	fog-clear	-
06/29 L	23	0	90%	green
06/30 S	24	0-5	100%, rain	-
07/21 L	24	0	hazy/sunshine	brownish grey
07/22 S	26	0-5	"	-
08/03 L	24	0-5	fog-clear	grey
08/04 S	27	0-5	clear	-
08/17 B	24	0-5	clear	grey green
09/09 L	20	5-10	overcast-clear	dark khaki
09/10 S	20	0-5	" "	-
10/13 B	12	0-5	90%, clear	-

* L = Lake
S = Stream
B = Both

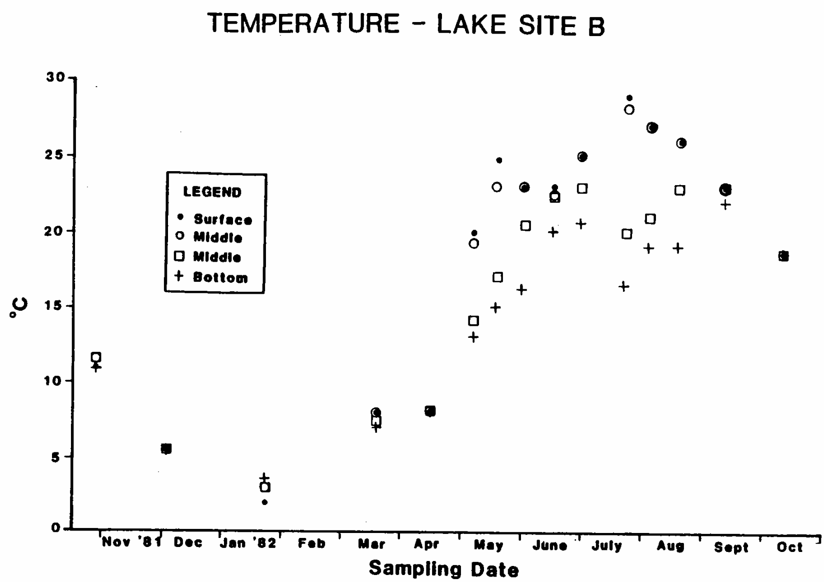


Figure 4-6. Water Temperature data at Lake Site B.

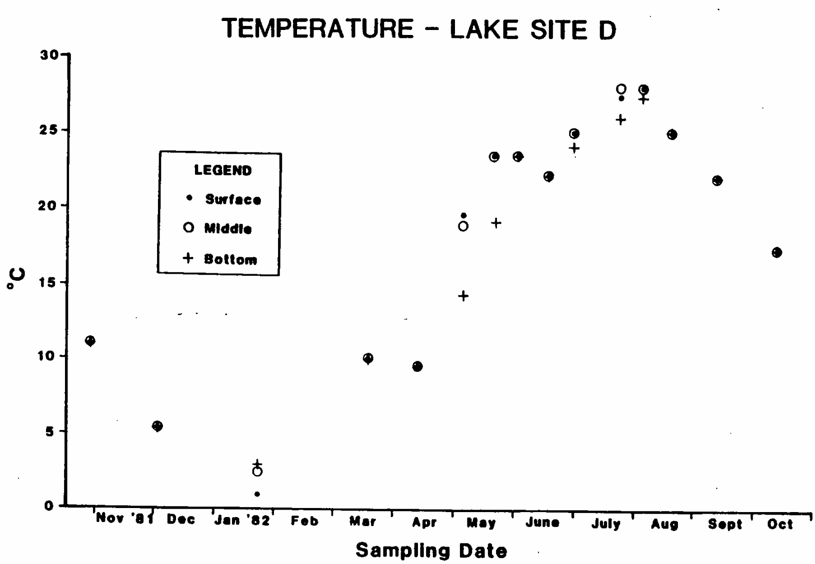


Figure 4-7. Water Temperature data at Lake Site D.

Temperatures in the streams follow the same seasonal pattern as the lake surface samples (Figure 4-9). Plum and Bear Creeks (Sites E and F) were consistently cooler than Beanblossom Creek. This may be due to several conditions including: greater groundwater influence, small stream size, steeper topography, and more forested (and thus more shaded) watersheds.

Dissolved oxygen concentrations decline during the year from about 11 ppm in January to 7 ppm in late summer (Figures 4-10 and 4-11). This decline is largely due to increased water temperatures since percent oxygen saturation levels remain relatively constant, varying between 70 and 100% saturation (Figures 4-12 and 4-13). The deeper waters at Site B become oxygen depleted from May through September. However, since this anoxic zone lies primarily in the original channel of Beanblossom Creek at depths below six meters (20 feet), only a small volume of water (5% of the total) is affected. Site D exhibits temporary oxygen depletion at the bottom depth for several summer samples. By October, there is no variation of DO with depth at either Sites B or D.

Temperature and oxygen characteristics of Lake Lemon indicate that the eastern pools of the lake have periods of complete mixing (holomixis) and stratification. This is probably due to wind mixing which accelerates vertical turbulence and replenishes the deeper waters by dispersion of oxygen from the surface layers. Considering that the lake, especially in the eastern end, is topographically exposed to the prevailing winds and has a large surface area to mean depth ratio, wind action is a sufficient force to cause complete mixing (Hutchinson 1957). Turbulent mixing due to inflowing water from Beanblossom Creek is also a major factor in the eastern pools of Lake Lemon.

The five stream sites have DO curves similar to that for Beanblossom Creek at Site G (Figure 4-14). Concentrations are high in the winter and drop throughout the spring and summer. Saturation values, however, remain more constant, ranging from 70-100%. Site G had DO saturation values consistently ten to 20% lower than the other stream sites (see Appendix A).

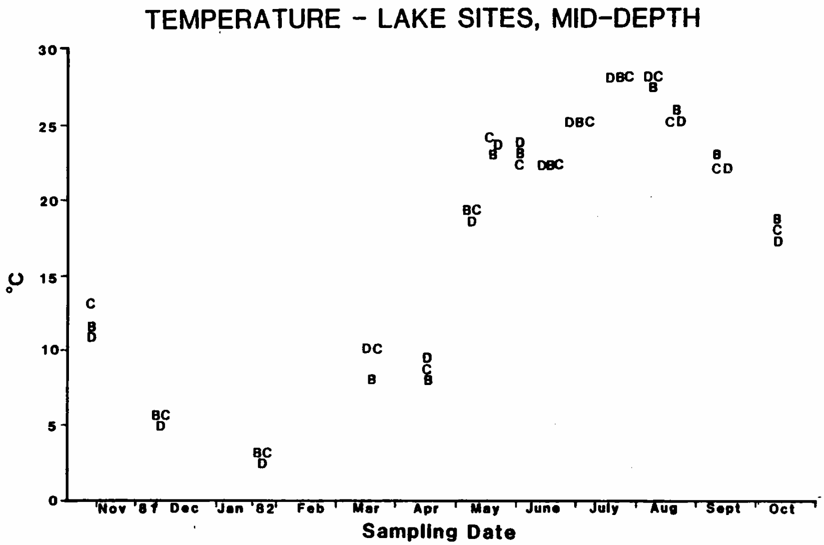


Figure 4-8. Water temperature data for all lake sites at mid-depth.

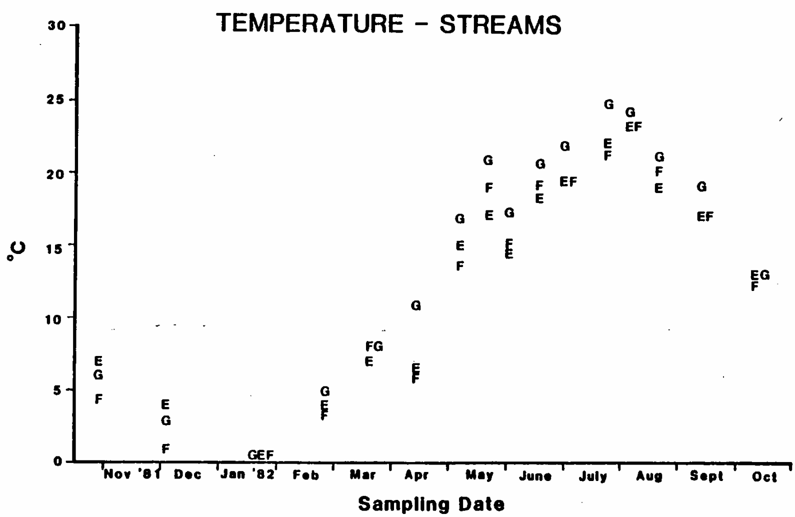


Figure 4-9. Water temperature data for Plum (E), Bear (F), and Beanblossom (G) Creeks.

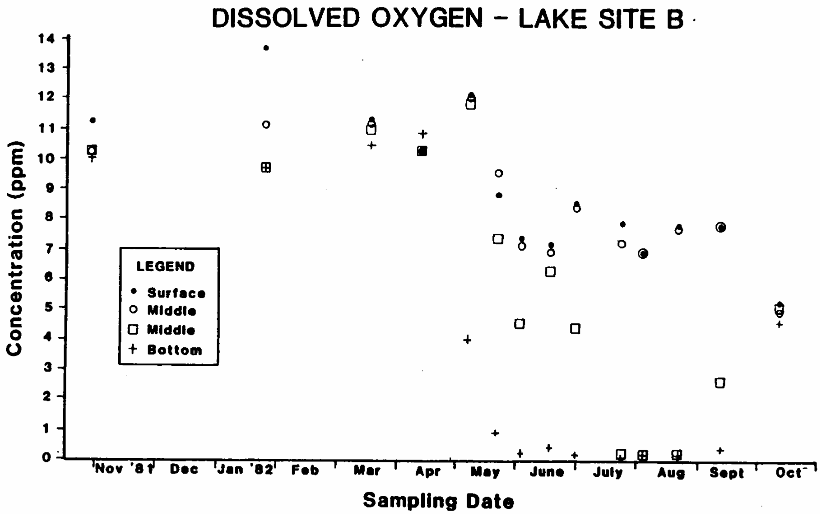


Figure 4-10. Dissolved oxygen data at Lake Site B.

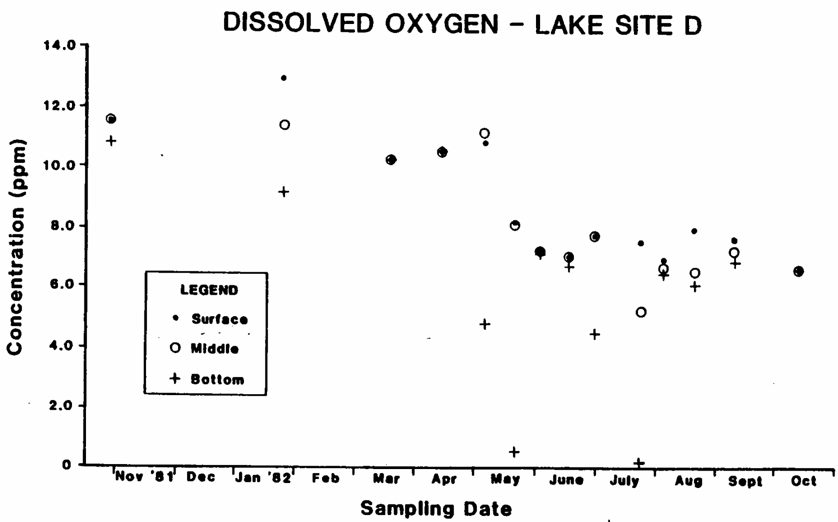


Figure 4-11. Dissolved oxygen data at Lake Site D.

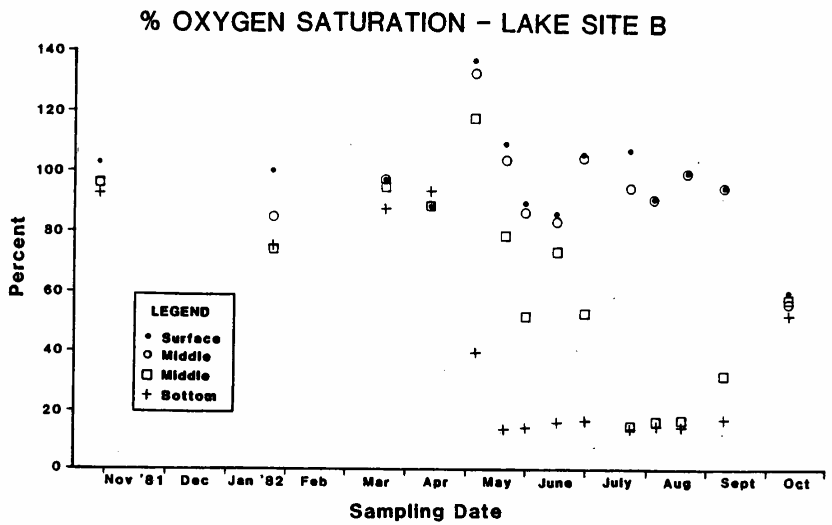


Figure 4-12. Dissolved oxygen saturation data for Lake Site B.

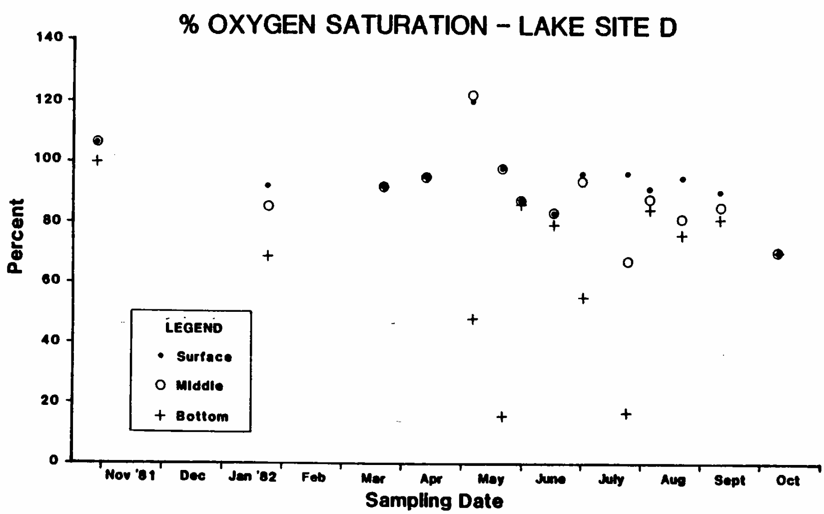


Figure 4-13. Dissolved oxygen saturation data for Lake Site D.

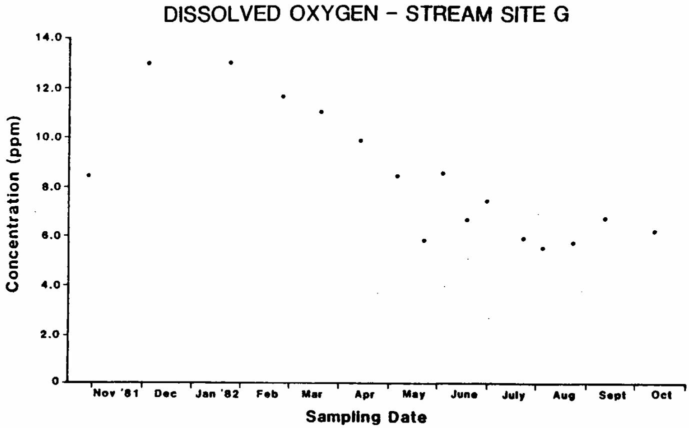


Figure 4-14. Dissolved oxygen data for Stream Site G.

4.3.3 Alkalinity and pH

Alkalinity samples were unaltered, stored on ice upon collection, and titrated with N/44 acid to pH 4.3 immediately on arrival at the laboratory. pH measurements were made in the field with a selective ion meter and a combination glass and reference electrode.

Alkalinity measures the quantity of those compounds in water, usually bicarbonate and carbonate ions, which allow water to resist large fluctuations in pH. This buffering action is important because it ensures a relatively constant environment for biological activity. Components of alkalinity such as carborate and bicarborate will complex some toxic heavy metals and markedlyreduce their toxicity. For these reasons, the U.S. EPA has recommended an alkalinity criterion of 20 mg/l or more as $CaCO_3$ for freshwater life except where natural concentrations are less (U.S. EPA 1976). Alkalinity results (Figures 4-15 and 4-16) indicate that Lake Lemon is only moderately buffered. The measured alkalinity values ranged from about 30 mg/l ($CaCO_3$) in early March to about 70 mg/l ($CaCO_3$) in September. The observed seasonal alkalinity changes probably result from increased biological production that occurred

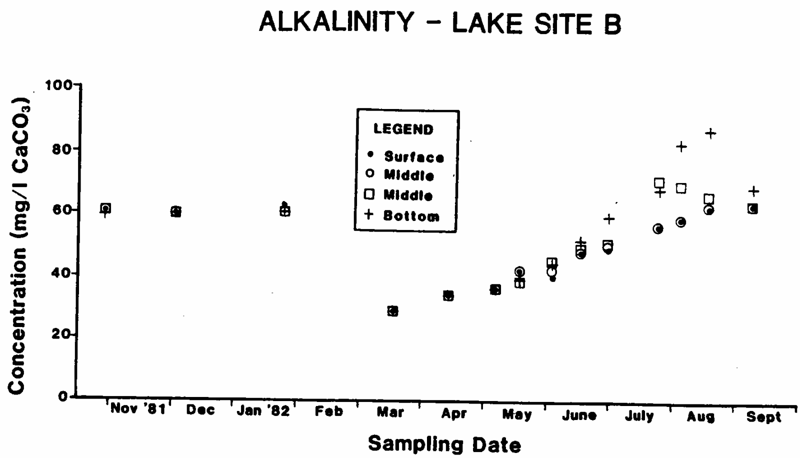


Figure 4-15. Alkalinity data for Lake Site B.

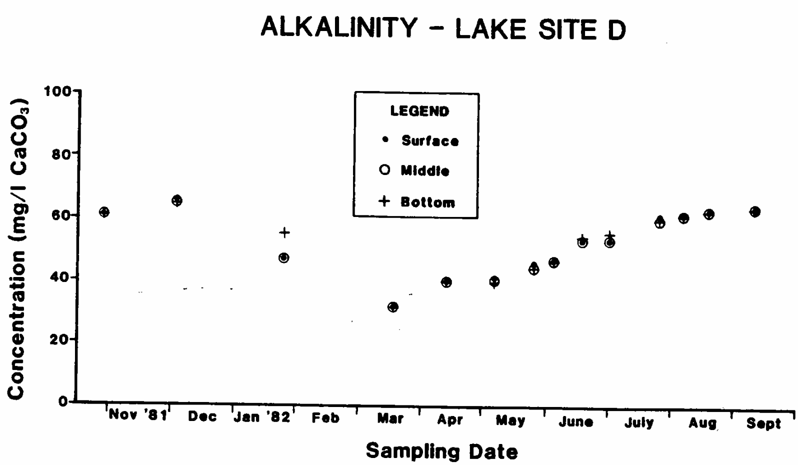


Figure 4-16. Alkalinity data for Lake Site D.

throughout the spring and summer. Alkalinity values for Lake Lemon follow a similar trend as those for Beanblossom Creek (see Figure 4-17) and appear closely correlated to discharge. Under base flow conditions, runoff is more influenced by the basin's geology which includes areas of limestone bedrock, thus alkalinity values are high. However, during periods of high runoff (March and June) the greater water volume results in less geologic influence and therefore lower alkalinity values.

The pH value is a measure of hydrogen ion activity. The range of this parameter in most natural waters that are buffered by bicarbonate ions is between six and nine. The pH measurements in Lake Lemon during 1981-82 ranged from 6.4 to 8.3. In Lake Lemon, pH values were low in the spring and gradually increased in the summer (Figure 4-18). Summer pH values at the deeper water depths (e.g., Site B_4) were lower than those of the surface waters. Reducing conditions caused by oxygen depletion are the likely cause of this. There was little difference in pH values between the eastern and western lobes of the lake.

Stream pH values were high in the winter, dropped in the spring, and then gradually rose during the summer (Figure 4-19). The lower values in January to March, which were also the periods of highest monthly discharge, were likely due to the more acidic pH of rain and snow.

4.3.4 Phosphorus

Total Phosphorus

Phosphorus samples were collected in acid-washed pyrex bottles, stored on ice in the field, and refrigerated at 4° C on arrival at the laboratory. Soluble reactive phosphorus (SRP) samples were filtered in the field and analyzed immediately upon return to the laboratory. Analysis of phosphorus was done by the ascorbic acid method according to Standard Methods (APHA 1980). Total phosphorus (TP) concentrations in Lake Lemon ranged from ten to 210 ug/l, although most values fell between 20 and 60 ug/l (Figures 4-20 and 4-21). There is no consistent pattern of concentration changes with depth until August, when deeper waters exhibit elevated TP levels,

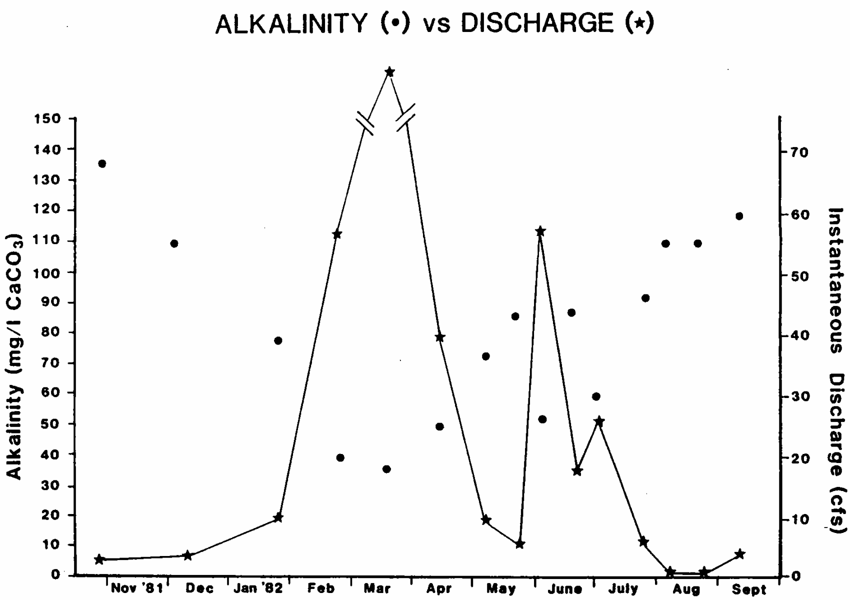


Figure 4-17. Alkalinity data vs. discharge at Beanblossom Creek Site G.

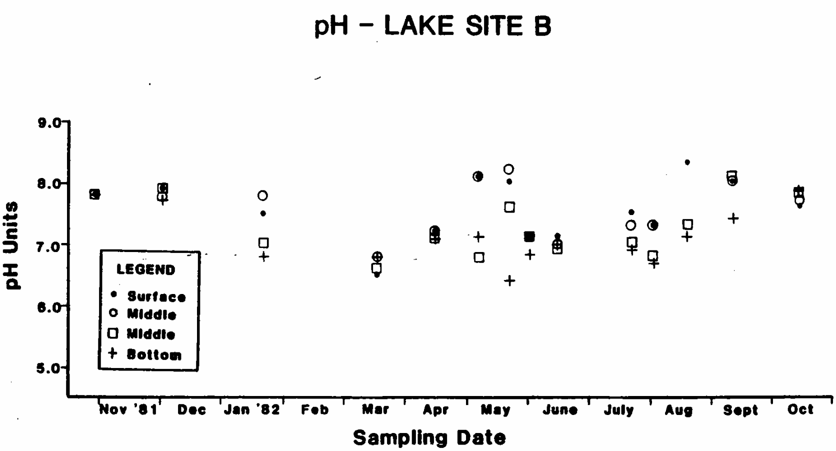


Figure 4-18. pH data for Lake Site B.

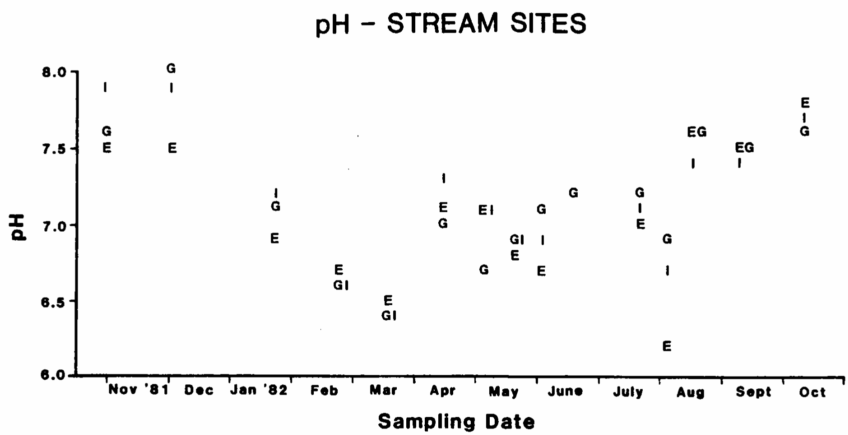


Figure 4-19. pH data for Plum (E), Beanblossom (G) and Upper Beanblossom (I) Creeks.

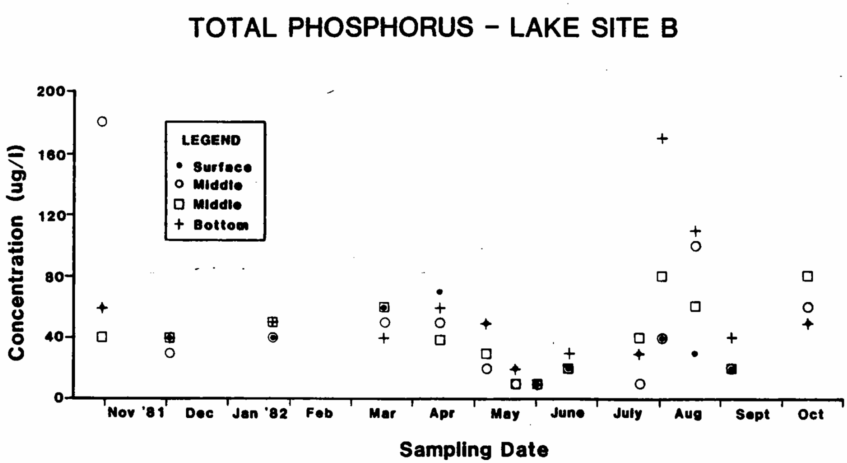


Figure 4-20. Total phosphorus data for Lake Site B.

particularly at Site B. These elevated levels are likely the result of phosphorus release from sediments under reducing conditions caused by oxygen depletion (or from picking up some bottom sediments with the water sample).

Epilimnetic total phosphorus concentrations are slightly higher in the eastern lobe of Lake Lemon than in the western lobe. This is probably the result of the higher suspended sediment loads in the eastern lobe (see Section 4.3.8) and the particulate phosphorus that it carries. Soluble reactive phosphorus concentrations do not show this trend .

Seasonally, springtime TP concentrations are higher than those of early summer. These may be related to spring runoff and particularly, the flow of Beanblossom Creek. For example, the TP peak at Site D in March (Figure 4-21) coincides with the greatest discharge we recorded for Beanblossom Creek during the study. The summertime rise in in-lake TP may also be related to slightly elevated TP levels in Beanblossom Creek (see Figure 4-22) and to sediment phosphorus release as mentioned previously.

Beanblossom Creek at Site G consistently had the highest concentrations of TP among the streams sampled. TP concentrations at Site G ranged from ten ug/l on two dates to 120 ug/l on two October samples (Figure 4-22). Plum Creek (Site E) on the other hand, consistently had the lowest TP concentrations, generally ranging between 20-30 ug/l. Bear Creek (Site F) also had low TP concentrations, except on two dates (May 19 and June 17). These dates correspond with higher suspended solids loads also recorded for Bear Creek. Total phosphorus concentrations for the upper reaches of Beanblossom Creek (Sites H and I) generally ranged between 20-50 ug/l.

The amount of inflowing nutrients that may be retained by a lake or reservoir is variable and will depend on (EPA 1976): a) the nutrient loading to the lake or reservoir; b) the volume of the euphotic zone; c) the extent of biological activities; d) the retention time within the lake basin; and e) the amount of discharge from the lake. All of these factors should be considered in evaluating nutrient inputs to lakes.

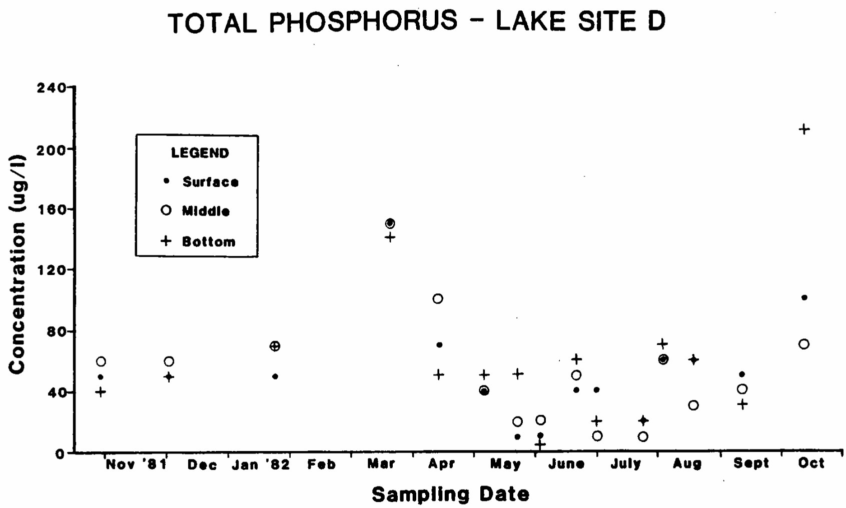


Figure 4-21. Total phosphorus data for Lake Site D.

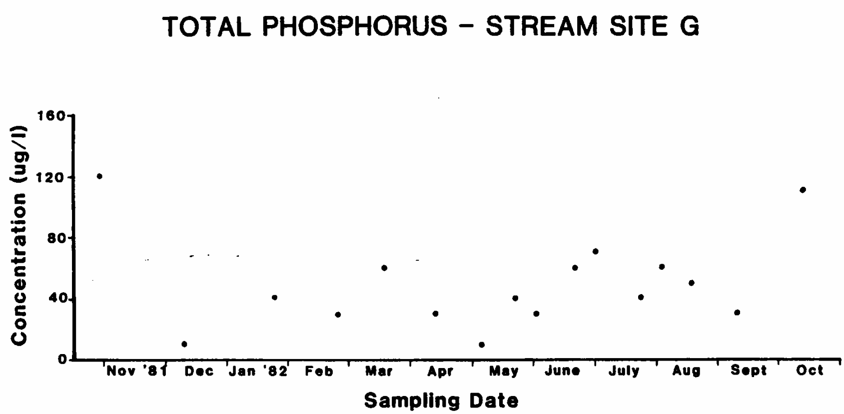


Figure 4-22. Total phosphorus data for Beanblossom Creek at Site G.

Total phosphorus concentrations of most unpolluted lakes are between ten and 50 ug/l (Wetzel 1975). Natural variation is high however, in accordance with the geochemical structure of the region. Epilimnetic TP concentrations ranging between 30 and 100 ug/l have been used to characterize eutrophic lakes, while hypereutrophic lakes can exhibit total phosphorus concentrations well in excess of 100 ug/l. According to these criteria, Lake Lemon would be classified as having sufficient TP levels to cause eutrophic conditions. However, since eutrophication implies biological overproductivity, an evaluation of the lakes biological communities (see Section 4.5) is also necessary before arriving at the conclusion that Lake Lemon is eutrophic.

Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) is the form of phosphorus that is biologically available to phytoplankton. SRP concentrations in Lake Lemon are either at or below the level of detection (10 ug/l) throughout the course of this study (Figures 4-23 and 4-24). At Site D in the eastern pool of Lake Lemon hypolimnetic SRP reached a level of 20 ug/l in July and early August. This corresponds to a similar increase in SRP for the same period at Site G in Beanblossom Creek. At Site B, hypolimnetic SRP concentrations are similarly low, suggesting that SRP release from the sediments is not significant. The high value recorded for early August may be due to contamination.

SRP concentrations in the streams were unusually low. In Beanblossom Creek at Site G, SRP concentrations were generally below ten ug/l, except for small peaks (up to 20 ug/l) on June 16, July 22, and August 4 (Figure 4-25). These same peaks are evident in Upper Beanblossom Creek (Site I) but at higher magnitudes (up to 60 ug/l). These peaks may be due to upper Beanblossom Creek's watershed having the highest acreage in agricultural land use of all the sub-basins in Lake Lemon's drainage basin.

Phosphorus Input Via Beanblossom Creek

Calculations of the estimated mass loading of soluble reactive phosphorus (SRP) and total phosphorus (TP) entering Lake Lemon via

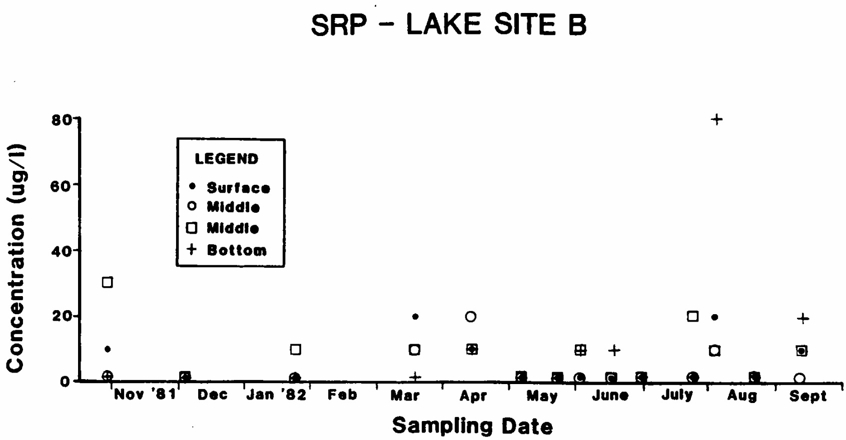


Figure 4-23. Soluble reactive phosphorus data for Lake Site B.

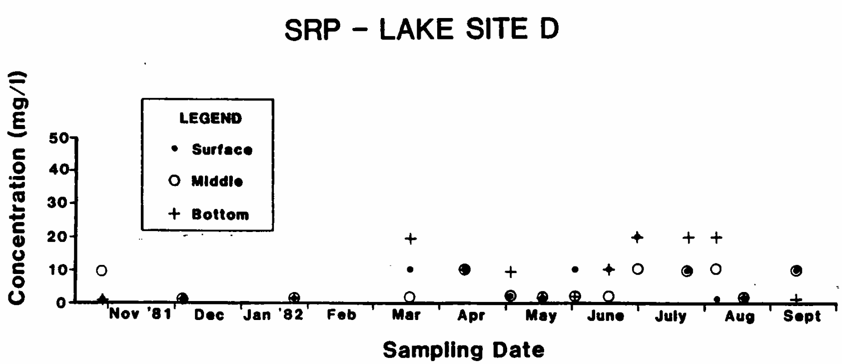


Figure 4-24. Soluble reactive phosphours data for Lake Site D.

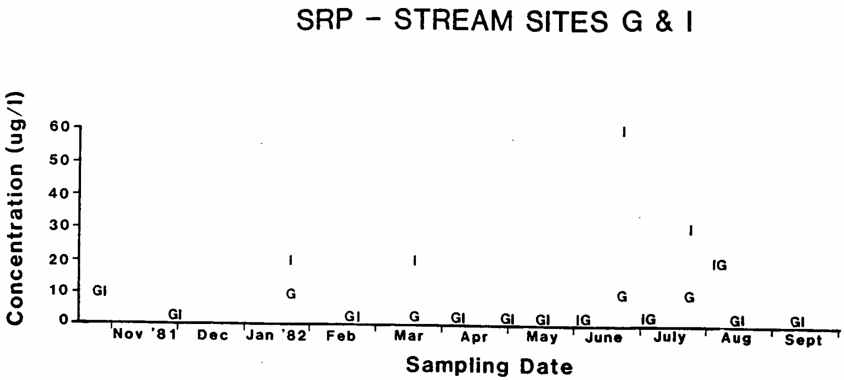


Figure 4-25. Soluble reactive phosphorus data for stream sites G and I.

Beanblossom Creek were made for the 1982 water year. Results from these calculations are shown in Table 4-5 and indicate that the annual load of SRP of 11,580 kg represents (at a maximum) 39 percent of the total input of phosphorus (29,372 kg). Almost two-thirds of the SRP analyses for Site G (Table 4-6) were reported as < ten ug/l but were assumed to be ten ug/l in order to estimate the mass loadings given in Table 4-5. As such, it is quite likely that the fraction of the total phosphorous content present as soluble reactive phosphorus is considerably less than 39 percent and that the estimated monthly loadings for SRP are overestimated by an unknown amount.

Table 4-5 also shows that both the SRP and TP loads are not evenly distributed throughout the year. For example, 63.5 percent of the annual load of SRP was estimated to have occurred during January 1982 and 84 percent of the annual SRP load took place during the period January-March, 1982. A similar trend was evident for TP loading, although the data for this parameter are less dramatic with about 68% of the annual phosphorous load estimated to have occurred during the period January-March, 1982.

TABLE 4-5. ESTIMATED MASS LOADING OF SOLUBLE REACTIVE PHOSPHORUS (SRP) AND TOTAL PHOSPHORUS (TP) FOR BEANBLOSSOM CREEK NEAR INFLOW TO LAKE LEMON

Month/Year	Estimated Average Discharge (ft^3/sec)	Estimated Monthly Mass Loading			
		SRP		TP	
		(kg/yrs)	(%)[1]	(kg/yr)	(%)[1]
10-81	2.2	22	0.2	108	0.4
11-81	3.0	32	0.3	149	0.5
12-81	28.0	275	2.4	1,350	4.6
1-82	182.0	7,350	63.5	8,500	28.9
2-82	116.0	1,100	9.5	5,350	18.2
3-82	132.0	1,240	10.7	6,200	21.1
4-82	72.0	720	6.2	3,550	12.1
5-82	23.0	235	2.0	1,130	3.8
6-82	44.0	419	3.6	2,140	7.3
7-82	10.0	103	0.9	495	1.7
8-82	3.6	38	0.3	178	0.6
9-82	4.5	46	0.4	222	0.8
	Total	11,580[2]	100	29,372	100

[1]percentage of estimated total load for 1982 water year.

[2]SRP loading of 11,580 kg represents 39% of the TP loading for the 1982 water year.

TABLE 4-6. CONCENTRATION OF SOLUBLE REACTIVE PHOSPHORUS (SRP) AND TOTAL PHOSPHORUS (TP) FOR BEANBLOSSOM CREEK AT SITE G

Sample Date	SRP (ug/l)	TP (ug/l)	SRP/TP (%)
10/28/81	10	120	8
12/02/81	<10	10	<100
01/20/82	10	40	25
2/24/82	<10	30	< 33
3/17/82	<10	60	< 17
4/13/82	<10	30	< 33
5/05/82	<10	10	<100
5/18/82	<10	40	< 25
6/01/82	<10	30	< 33
6/16/82	10	60	17
6/29/82	10	70	17
7/21/82	10	40	25
8/03/82	20	60	33
8/17/82	<10	50	< 20
9/09/82	<10	30	< 33
10/13/82	-	110	-

Concentration data of soluble reactive phosphorus and total phosphorus for Beanblossom Creek at Site G (near the inflow to Lake Lemon) are listed in Table 4-6. As noted earlier, the SRP levels are frequently < 10 ug/l with a maximum of 20 ug/l in August, 1982. Levels of total phosphorus range between 10-120 ug/l with a median of 40 ug/l.

4.3.5 Nitrogen

Nitrogen samples were acidified with H_2SO_4 in the field, stored on ice and refrigerated upon arrival at the laboratory. Within a week total Kjeldahl nitrogen (TKN) samples were analyzed by the macro-digestion procedure according to Standard Methods (APHA 1981). TKN results are expressed as the sum of free ammonia and organic nitrogen in mg/l. Ammonia and nitrate analyses were conducted using a Wescon Ion Analyzer.

The fractionations of nitrogen are reported (and determined) in various ways in published analyses. The terms used here are as follows:

Total Kjeldahl Nitrogen (TKN)	=	measured
Nitrate-Nitrogen	=	measured
Ammonia-Nitrogen	=	measured
Total Nitrogen	=	TKN + NO_3
Organic Nitrogen	=	TKN - NH_4
Inorganic Nitrogen	=	NO_3 + NH_4

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) concentrations for Sites B and D are presented in Figures 4-26 and 4-27. TKN concentrations for Lake Lemon are rather low, ranging from 0.2 to 0.8 mg/l over most of the study period, with an occasional anomalous value, most likely due to early difficulties with the micro-digestion technique. Thereafter, a macro-digestion was used and gave more reliable results. At all three lake sites TKN concentrations rose in August and September, as the lake became more productive and as chemical weed control (and macrophyte die-off) increased. This pattern was similar for

TKN - LAKE SITE B

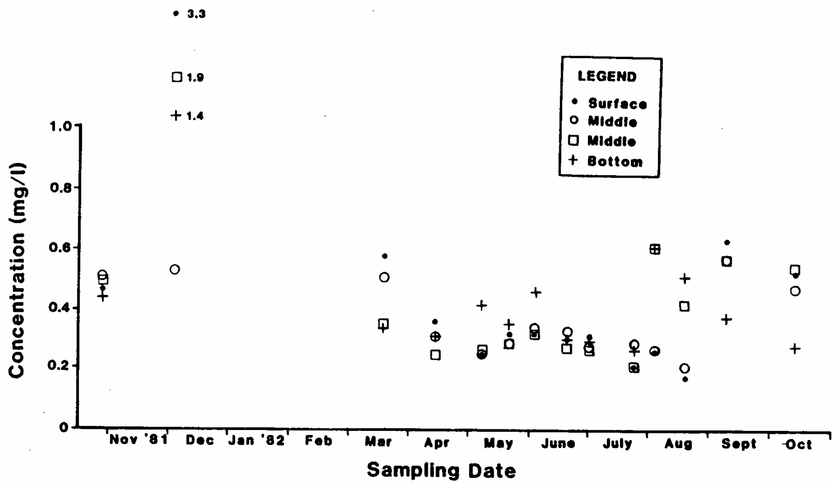


Figure 4-26. Total Kjeldahl nitrogen data for Lake Site B.

TKN - LAKE SITE D

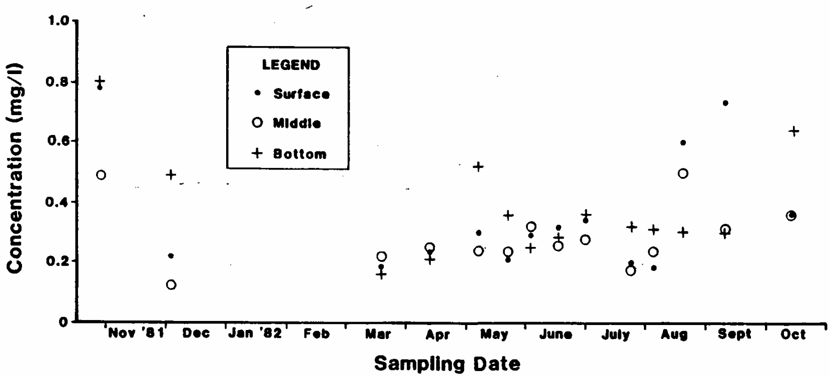


Figure 4-27. Total Kjeldahl nitrogen data for Lake Site D.

Beanblossom Creek as well (see Figure 4-28). TKN inputs in the watershed also increased in August. At Site G on Beanblossom Creek, TKN concentrations reached their summer maximum (0.5 mg/l) on August 18. Sites H and I on the upper reaches of Beanblossom Creek had peak values of 0.6 mg/l on the same date. The maximum concentration of TKN at Site I was 0.74 mg/l on June 16, the same day that TP, SRP, suspended solids, and fecal coliform bacteria peaked. These elevated values may be due to increased runoff from a rainfall that occurred on this date.

Nitrate-Nitrogen

The nitrate graphs show values that are in the 0.2 to 0.5 mg/l range from October through January (Figure 4-29). During the spring run-off period, nitrate concentrations increase to about 0.8 mg/l and then gradually decline to near zero in June and July. In September the values rise again to their highest levels. At Site B the values slowly rise from July until September but at C and D the values jump in a two-week time period. Maximum September values at Sites C and D were 1.2 mg/l and 2.02 mg/l respectively.

The drop in the summer nitrate concentrations indicates that the nitrogen is being photosynthetically consumed used by phytoplankton and macrophytes. The rise in late summer suggests either reduced uptake or possibly a release of nitrate by senescent vegetation. Nitrate concentrations in Beanblossom Creek at Site G follow this same pattern (Figure 4-30). Nitrate concentrations are quite variable among the streams with no evident pattern. The highest value recorded was 1.4 mg/l at the North Fork of Beanblossom Creek (Site H) in September. All streams had low nitrate concentrations in July and August.

Ammonia-Nitrogen

Ammonia-nitrogen levels drop throughout the spring and remain very low all summer (Figures 4-31 and 4-32). At Site B, hypolimnetic ammonia-nitrogen concentrations rise during the summer to a maximum value of 1.2 mg/l in early August. This is expected under the reducing conditions that exist at Site B_4 during this

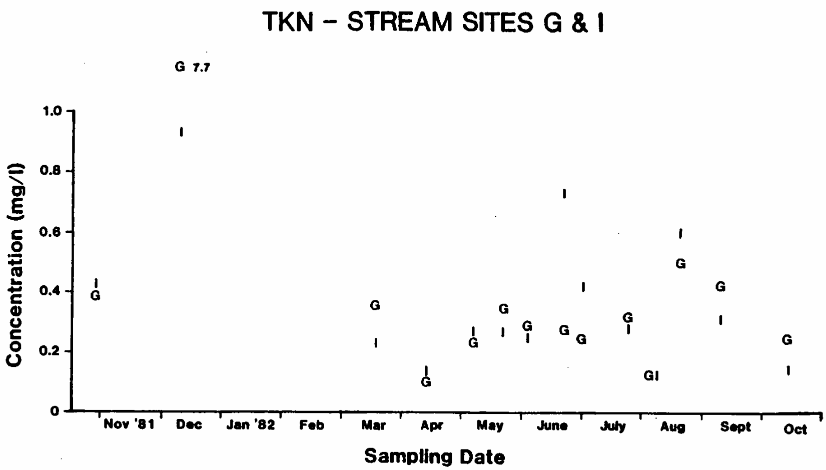


Figure 4-28. Total Kjeldahl nitrogen data for Beanblossom (G) and Upper Beanblossom (I) Creeks.

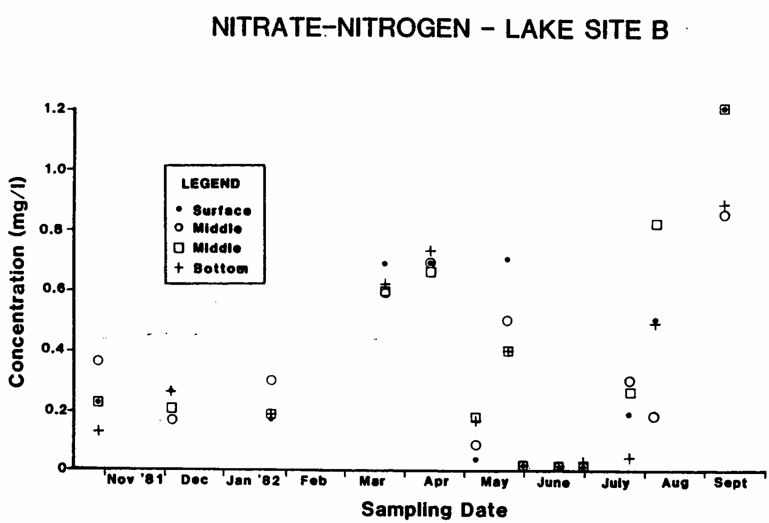


Figure 4-29. Nitrate data for Lake Site B.

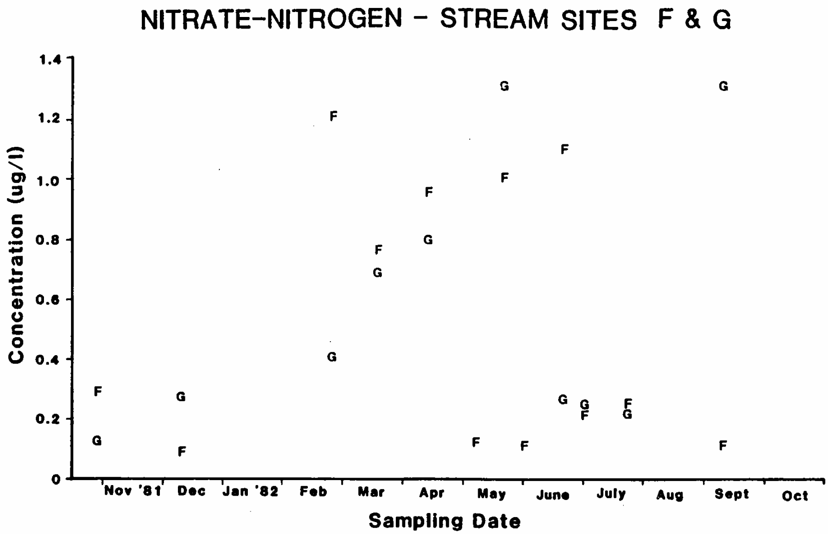


Figure 4-30. Nitrate data for Bear (F) and Beanblossom (G) Creeks.

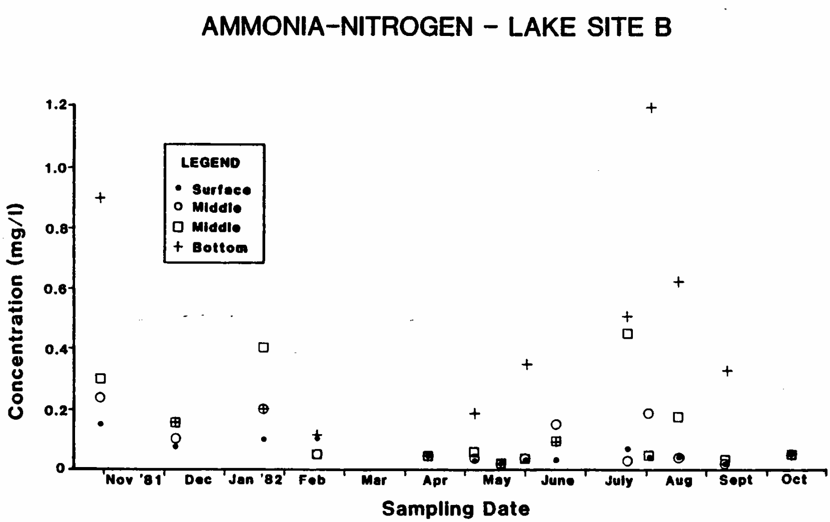


Figure 4-31. Ammonia data for Lake Site B.

period. Stream ammonia-nitrogen levels were highest in December 1981, reaching maximum values of 0.8 mg/l at Site G (Beanblossom Creek) and Site I (Upper Beanblossom Creek) and 0.38 at Site H (North Fork Beanblossom Creek). For the remaining months of the study, ammonia-nitrogen concentrations at the stream sites remained at or below 0.2 mg/l.

4.3.6 Chlorophyll a

Chlorophyll a samples were collected in opaque polyethylene containers, stored on ice in the field and refrigerated upon arrival at the lab. Samples were filtered within 48 hours. Filters were stored frozen in the dark and analyzed for chlorophyll a on a spectrophotometer by the trichromatic method and corrected for phaeophyton.

Chlorophyll is the pigment found in all plants and is used in the process of photosynthesis. It can thus be used as an indirect measure of the standing crop of photosynthetic organisms in a lake (Vollenweider 1968). This measurement is only an estimate because all species do not contain equivalent amounts of chlorophyll. The success of chlorophyll extraction can vary from species to species as well.

Figure 4-33 contains a plot of chlorophyll a data for Lake Site B, which is representative of the other lake sites. Most lake values for chlorophyll a fall around the ten mg/l range until August and September, when a peak of 150 mg/l occurred on August 3. This peak occurred at the other lake sites as well. SRP concentrations and algal biomass were also elevated on this date for the lake sites and for Beanblossom Creek (see Sections 4.3.4 and 4.5). The range of chlorophyll a concentrations for surficial samples (3-40 mg/m^3 excluding the one peak value) indicate high productivity in Lake Lemon when compared to other lakes (Figure 4-34). However, this conclusion is not entirely consistent with the algal data (see Section 4.5).

The Beanblossom Creek sampling sites also show a peak on August 3. Site G reached a maximum of 15 mg/m^3 while Sites H and I both had peak values of 5 mg/m^3. Chlorophyll a concentrations for Plum

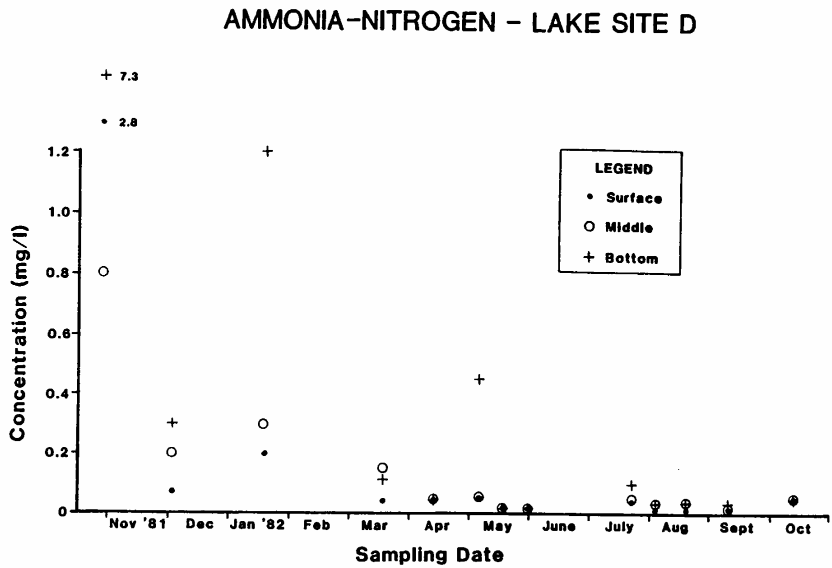


Figure 4-32. Ammonia data for Lake Site D.

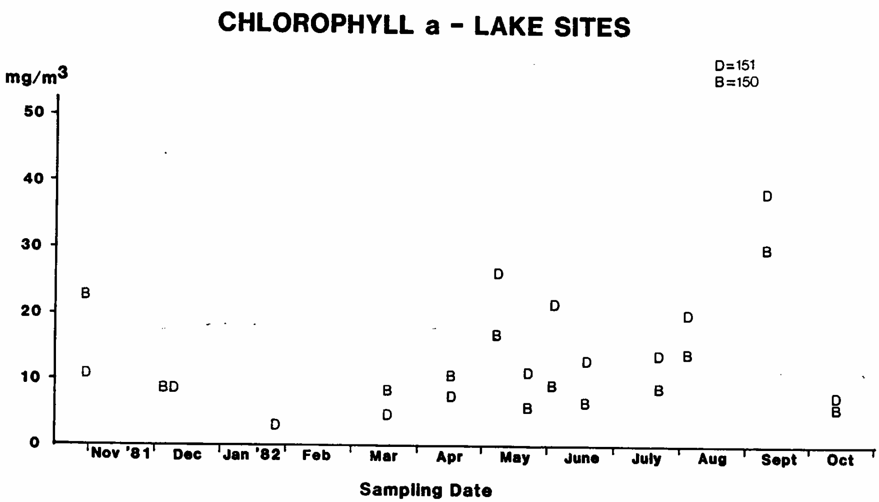


Figure 4-33. Chlorophyll a data for Lake Sites B and D.

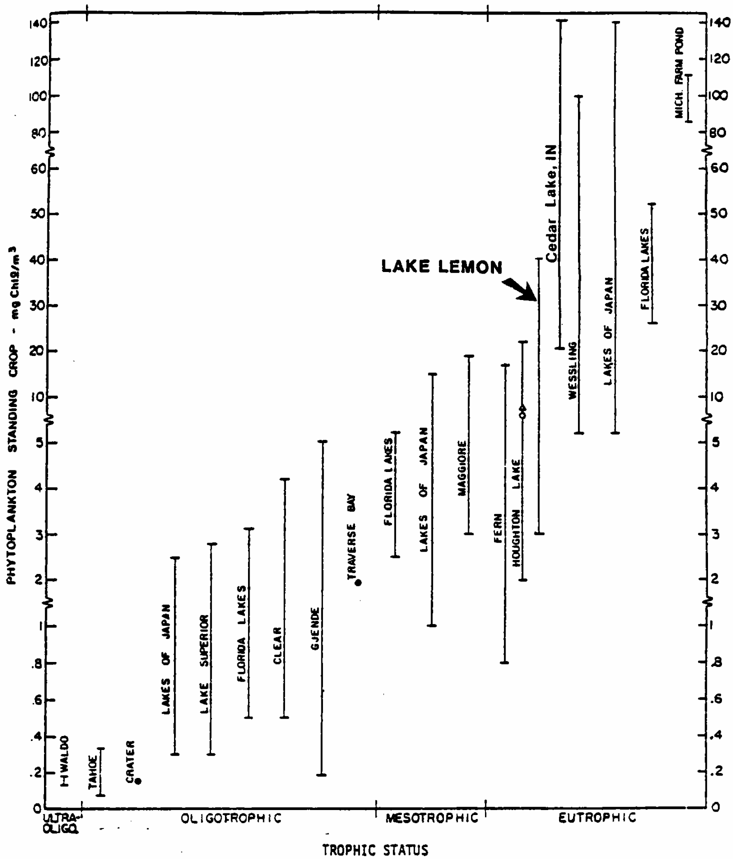


Figure 4-34. Comparative phytoplankton standing crops of several lakes in North America, Europe, and Asia. Lake Lemon is indicated.

(E) and Bear (F) Creeks remained below 2 mg/m^3 throughout the study period.

4.3.7 Secchi Disk Transparency

Secchi disk transparency is a function of the reflection of light from the disk's surface. It is influenced by the light absorbance characteristics of the water and by the content of dissolved and suspended matter. In productive waters, Secchi disk transparency measurements are affected greatly by particulate matter and can be used as a rough estimate of the density of phytoplankton populations (Wetzel 1975).

Secchi disk measurements from Lake Lemon are closely correlated with discharge from Beanblossom Creek (Figure 4-35), particularly in the spring when suspended sediment loads are high. High discharges in March and June result in low Secchi disk values, to as low as 12cm at Site B following the March runoff. In the summer, Secchi disk transparency is more influenced by algae productivity and possibly degradation products of chemically-controlled macrophytes (esp. Myriophyllum spicatum). Transparency values increase from east to west (Site D to Site B) in Lake Lemon, again demonstrating the influence of Beanblossom Creek and indicating that some of the creek's sediment load drops out as its sediment carrying capacity is diminished as the creek enters the lake.

4.3.8 Suspended Solids

Suspended solids concentrations were determined using the standard filtering technique described in Standard Methods (APHA 1981). The values are below 40 mg/l for almost all the samples, except for Site D in March, which coincided with a heavy run-off event (Figure 4-36). Generally, Site D has the highest in-lake suspended solids concentrations, most likely due to the influence of Beanblossom Creek. Suspended solids concentrations of water flowing out of the lake at Site A are all below 20 mg/l except on one occasion in October, 1981. The pattern of suspended solids concentrations across the lake illustrates that Lake Lemon functions as an active settling basin for sediments entering from Beanblossom

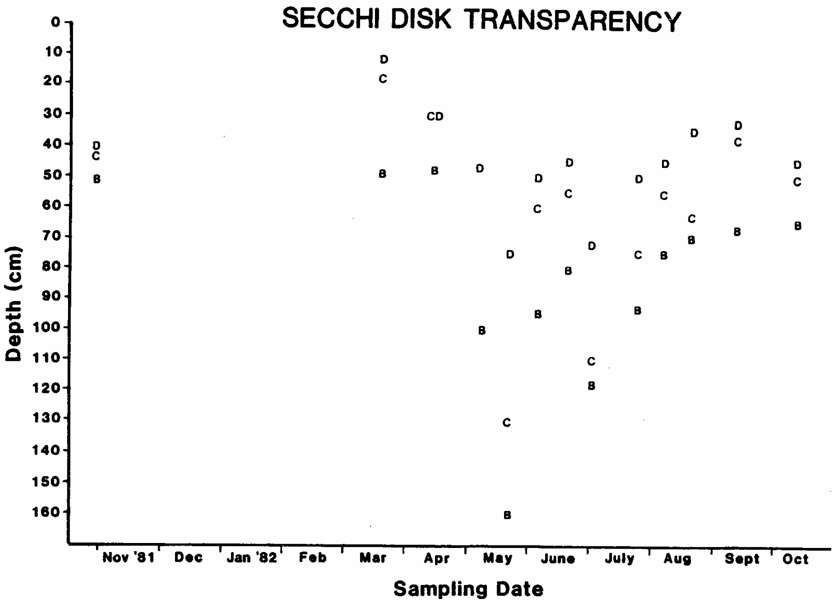


Figure 4-35. Secchi disk transparency data for all lake sites.

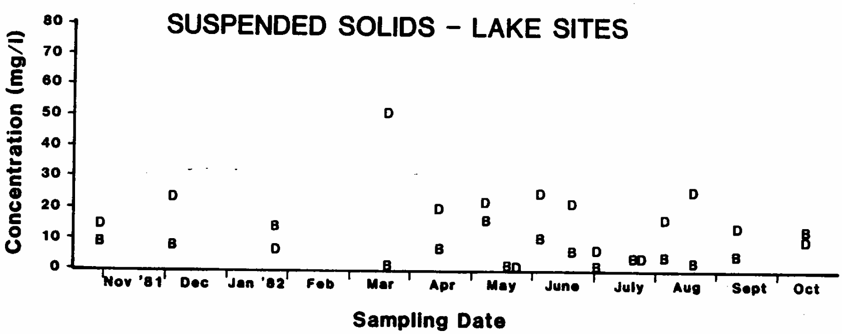


Figure 4-36. Suspended solids data for surficial samples from Lake Sites B and D.

Creek. For most samples at the three lake sites, the bottom depths contained higher suspended solids concentrations. This may be indicative of typical suspended solids settling behavior.

Except for isolated cases, Plum and Bear Creeks (Sites E and F) had the lowest suspended solids concentrations (Figure 4-37). These stream basins also have the lowest percentage of lands in agriculture. The upper reaches of Beanblossom Creek (Sites H and I) were next lowest, with Site H having consistantly higher levels than Site I. Beanblossom Creek at Site G consistently had the highest suspended solids concentrations of the streams sampled. Values ranged up to 42 mg/l. High suspended solids loads in the streams could usually be traced to specific events which had occurred. For example, the high (41 mg/l) concentration at Site H in January was likely due to streambank modifications (grading) by a private landowner above the sampling site and the high stream discharge (Figure 4-5) which followed them.

Annual sediment loading to Lake Lemon from Beanblossom Creek was estimated in the following manner:

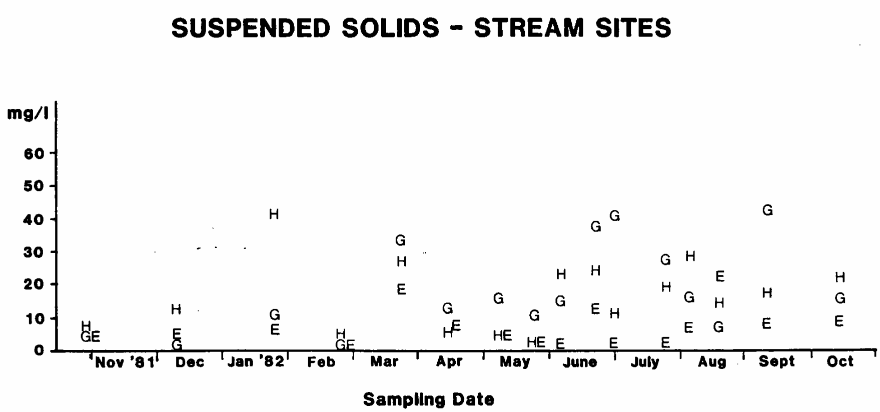


Figure 4-37. Suspended solids data for Plum (E), Beanblossom (G), and North Fork Beanblossom (H) Creeks.

1. Instantaneous discharge (cfs) and instantaneous sediment load (tons/day), collected during the 1980 and 1981 water years at the USGS gage on Beanblossom Creek at Beanblossom, were graphed (Figure 4-38)
2. The graph was then used to estimate mean daily sediment load from the mean monthly discharge, measured during the study period (1981-1982).
3. Daily loads were converted to monthly load (tons/month)(see Table 4-7).
4. Annual load at the USGS gage, which drains 26% of Beanblossom Creek, was adjusted to estimate the total annual sediment load from Beanblossom Creek as it enters Lake Lemon.

An annual sediment load to Lake Lemon from Beanblossom Creek of 2573 tons/yr. was estimated using this method.

Annual sediment load in tons/yr was converted to a volumetric load by using an average bulk density value (0.87 g/cm^3), determined from 22 Lake Lemon sediment samples by the Indiana Geological Survey (Hartke and Hill 1974). This yielded a volumetric annual sediment load of 2,689 m^3 (3,523 yd^3). Hartke and Hill (1974) estimated that approximately 94,000 yd^3 of sediment had been deposited in Lake Lemon during the period of 1953-1973, or about 4,700 yd^3/yr. Estimated sediment load from Beanblossom Creek during 1981-82 represents 75% of the estimated historical annual load to Lake Lemon, less the amount of suspended sediments discharged from the lake.

4.3.9 Fecal Coliform Bacteria

Fecal coliform bacteria are the normal inhabitants of the intestinal tract of warm-blooded animals, including humans. They are therefore present in fecal matter and are numerous in domestic wastewater. Consequently, the presence of large numbers of fecal coliform bacteria in lake water is indicative of potential wastewater contamination. High bacterial counts also suggest the possibility of additional nutrient sources to a lake since domestic

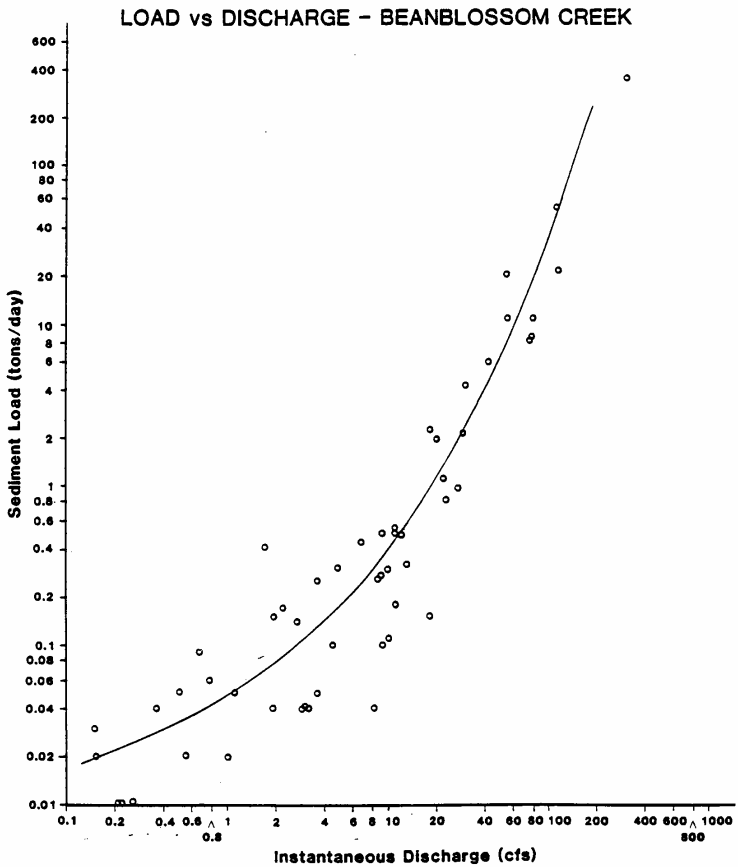


Figure 4-38. Relationship between discharge and sediment load for Beanblossom Creek. Data points were derived from measurements made at the USGS gage at Beanblossom during the 1980 and 1981 water years.

TABLE 4-7. MEAN MONTHLY DISCHARGE AND ESTIMATED MONTHLY SEDIMENT LOAD OF BEANBLOSSOM CREEK AT BEANBLOSSOM, IN

Month	Mean Monthly Discharge (ft^3/sec)	Sediment Load (tons/day)	Monthly Sediment Load (tons/month)[2]
October 1981	0.97	0.05	1.5
November	1.31	0.06	1.8
December	10.2	0.53	15.9
January 1982	58.7	9.80	294.0
February	38.7	3.80	114.0
March	43.5	4.90	147.0
April	24.7	1.75	52.5
May	8.7	0.35	10.5
June	15.7	0.76	22.8
July	4.04	0.15	4.5
August	1.57	0.07	2.1
September	1.92	0.08	2.4
TOTAL			669.0 tons/year

[1] From Figure 4-5
[2] Daily load x 30 days/month

wasteater contains high levels of nitrogen, phosphorus and other nutrients..

Fecal coliform bacteria counts were measured by the membrane filter technique according to Standard Methods (APHA 1981). When compared to Indiana's water quality standards of 200 or 400 fecal coliform bacteria per 100 ml for full-body contact recreation, the measured values for lake samples were within the standards except for isolated cases (Figure 4-39). The high counts on August 3 do not correlate with inputs from Beanblossom Creek and may be due to

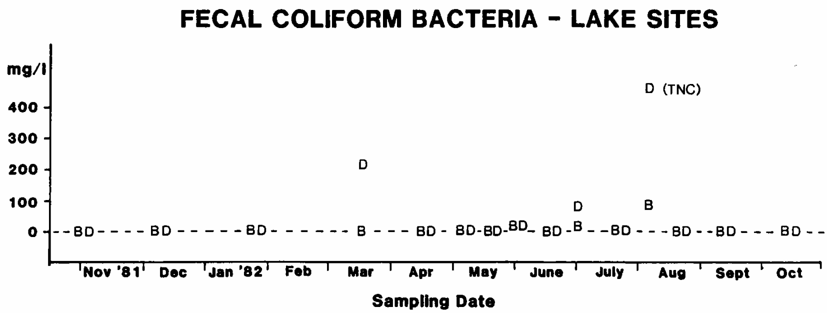


Figure 4-39. Fecal coliform bacteria data for Lake Sites B and D.

sample contamination. Plum Creek (Site E) generally had the fewest fecal coliform bacteria in samples collected (Table 4-8). Beanblossom Creek (Site G) had the highest mean counts. Bear Creek (Site F) had a number of violations (>400/100ml) that may be related to several summer camps located in its drainage basin. Violations at other sites could not be traced to specific causes.

4.4 SEDIMENTS

4.4.1 Chemical Properties

Methods

Sediment samples were collected on October 27, 1982 from eight locations in Lake Lemon and Beanblossom Creek (Figure 4-40). A Ponar dredge, which samples from the sediment surface, was used to collect all samples. Sediments to be analyzed for total phosphorus (TP), total Kjeldahl nitrogen (TKN), and metals were placed in whirl-pac bags and stored at 4°C until analyzed.

Total phosphorus was determined by the ascorbic acid method; TKN by macro-digestion; and metals were dried, acidified, digested, and

TABLE 4-8. FECAL COLIFORM BACTERIA DATA (COLONIES/100 ml) FOR STREAM SITES

	Sample Site				
Date	Plum Cr. (E)	Bear Cr. (F)	Beanblossom Cr. (G)	N. Fork Bbl. Cr. (H)	Upper Bbl. Cr. (I)
10-29-81	9	52	109	42	110
12-09-81	0	28	70	50	86
01-21-82	9	8	48	27	67
02-24-82	8	28	240	18	72
03-18-82	12	32	124	80	118
04-14-82	22	6	152	44	120
05-05-82	2	752	82	40	178
05-19-82	160	1,910	400	630	1,570
06-02-82	30	34	184	252	82
06-16-82	1,024	708	370	264	TNC
07-22-82	112	154	220	190	104
08-04-82	140	208	184	TNC	146
08-18-82	70	70	440	260	290
09-10-82	226	149	230	300	421
Mean[2]	62	171	204	169	150
No. of violations[3]	1	3	2	2	3

[1] Too numerous to count

[2] Values over 1000/100 ml not included

[3] Exceeding the Indiana standard for full-body contact recreation

SEDIMENT SAMPLING LOCATIONS

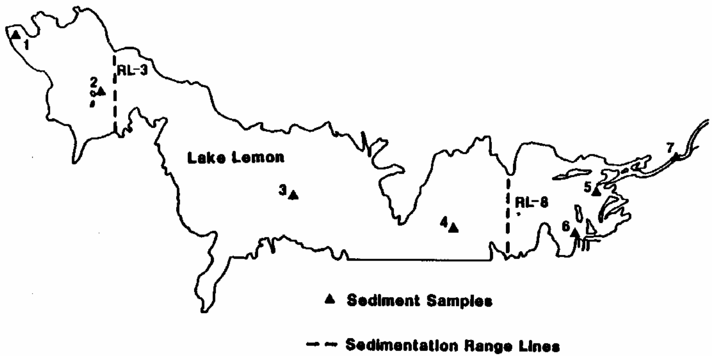


Figure 4-40. Locations of sediment collection sites and the sedimentation study range lines.

read on an atomic absorption spectrophotometer. All procedures were completed according to Standard Methods (APHA 1981).

Results

Phosphorus. Total phosphorus concentrations in Lake Lemon's surficial sediments are presented in Table 4-9. The highest in-lake concentration (542 mg/kg dry wt.) was found in sediments collected near the dam at Site 1 (Figure 4-40). This may be related to the higher percentage of clay-sized sediment particles (see Section 4.6.2) in the western end of the lake, since clay soils have a greater capacity to adsorb phosphorus. Phosphorus concentrations also decrease with increasing distance moving upstream from the mouth of Beanblossom Creek.

Total phosphorus concentrations in Lake Lemon sediments are generally lower than other Indiana Lakes for which data exist. Theis and McCabe (1978) report TP levels in the upper 3 cm of two hypereutrophic lakes, Stone Lake and Lake Charles East, to be 3420 mg/kg (dry wt.) and 2280 mg/kg respectively. In eutrophic Cedar Lake, Indiana, TP levels in surficial sediments ranged from 712 to 1067 mg/kg (dry wt.) (Echelberger et al. 1984). In two eastern Indiana reservoirs, Versailles Lake and Brush Creek Reservoir, TP concentrations in surficial sediments were reported to be 221 mg/kg and 287 mg/kg dry weight respectively (Echelberger et al. 1983).

Phosphorus release from lake sediments is a complex reaction that is closely related to iron forms and availability. In eutrophic lakes having low dissolved oxygen concentrations in the summer, iron is reduced and the solubility of phosphorus increases. Likewise, under oxidized conditions, the phosphate is more strongly adsorbed onto a ferro-hydroxy precipitate. Release of sediment phosphorus by this mechanism in Lake Lemon is presumed not to be significant due to the generally well-oxygenated bottom waters.

Nitrogen. In-lake total Kjeldahl nitrogen (TKN) concentrations in Lake Lemon surficial sediments ranged from 1148 to 2053 mg/kg (dry wt.), with concentrations increasing from east to west. Lakes are relatively rich in nitrogen since nitrogen inputs as organic matter

TABLE 4-9. TOTAL PHOSPHORUS AND TOTAL KJELDAHL NITROGEN CONCENTRATIONS IN LAKE LEMON SURFICIAL SEDIMENTS

Sample	Total Phosphorus (mg/kg dry wt.)	TKN (mg/kg dry wt.)
1	542	2,018
2	426	2,053
3	202	1,548
4	197	1,148
5	306	1,026
6	253	1,562
7	290	1,364
8	182	1,164

occur at relatively high rates. Thus, lakes which have highly organic sediments will also have higher concentrations of nitrogen in the sediments. For example, in Cedar Lake, Indiana, where the sediments are composed of 20% organic matter, TKN levels in sediments are also high (11,000 mg/kg dry wt.) (Echelberger et al. 1984). Lake Lemon's sediments, on the other hand, have only a 2-4% organic matter content (see Section 4.6.2) and thus have proportionately lower nitrogen levels.

<u>Metals</u>. The presence of heavy metals in high concentrations in lake sediments is an important concern to the analysis of lake quality. Depending on conditions, sediments may be a source of metals to the water column or they may be a sink for allochthonous inputs from the watershed.

Lake Lemon surficial sediments were analyzed for seven metals: cadmium, chromium, copper, iron, lead, nickel, and zinc. Results are presented in Table 4-10. Because of the lack of standards for metals levels in sediments, we have used EPA interim guidelines for comparisons in our analysis (U.S. Environmental Protection Agency 1977). These guidelines were developed by Region V, U.S.

TABLE 4-10. METALS CONCENTRATIONS IN LAKE LEMON SURFICIAL SEDIMENTS (ALL UNITS mg/kg DRY WT.)

Sample	Cd	Cr	Cu	Fe	Pb	Ni	Zn
1	1.2	21.7	25.4	43,050	41	205	121
2	1.2	20.9	23.8	42,230	33	205	117
3	0.8	11.5	11.1	6,560	12	94	56
4	0.8	11.9	11.9	19,680	12	102	66
5	0.8	11.1	11.9	20,910	16	98	66
6	0.8	12.3	11.5	19,270	20	102	65
7	0.8	12.7	12.7	20,090	20	98	66
8	1.2	13.9	13.9	21,730	20	107	75
EPA Guidelines							
heavily polluted	>6	>75	>50	>25,000	>60	>50	>200
non polluted	-	<25	<25	<17,000	<40	<20	<90

Environmental Protection Agency for making immediate decisions regarding the disposal of dredged material from Great Lakes harbors. The guidelines have not been adequately related to the impact of sediments on lakes and are considered interim guidelines until more scientifically sound guidelines are developed.

Cadmium and chromium levels in Lake Lemon sediments are well below the EPA guidelines. Literature values for these metals are scarce, however Forstner (1977) found cadmium concentrations of 2.5 mg/kg in the Lower Rhine River in Germany. Of this total, only 2% was from natural origin, the remaining 98% being derived from urban and agricultural runoff and atmospheric pollution.

Copper concentrations in Lake Lemon sediments ranged from 11.1 to 25.4 mg/kg, which are largely unpolluted by EPA's classification (<25 mg/kg). As much as 80% of the copper present in lake sediments is from human inputs, largely algicides (Forstner 1977). A maximum copper concentration in Cedar Lake sediments of 63 mg/kg was reported by Echelberger et al (1984) while some Wisconsin lakes had concentrations in excess of 200 mg/kg (Shukla et al. 1972).

Iron concentrations in Lake Lemon sediments near the dam (42,000 mg/kg) fell above EPA's heavily polluted range (>25,000 mg/kg).

However, iron levels in sediments are strongly influenced by geologic conditions and it is not uncommon to find high iron levels where such conditions prevail. In the Lake Lemon watershed, iron is found in relatively high concentrations in the bedrock. This no doubt accounts for the high iron levels in the lake sediments.

Lead concentrations in Lake Lemon sediments range from 12 to 41 mg/kg dry wt. These levels fall largely below the EPA guideline for nonpolluted sediments (<40 mg/kg). Lead inputs to lakes are due largely to cultural inputs, primarily fossil fuel combustion.

Nickel concentrations in Lake Lemon sediments reached a maximum value of 205 mg/kg, which is substantially greater than the EPA guidelines for heavily polluted sediments (>50 mg/kg). Nickel seldom occurs in nature in its elemental form.

Zinc concentrations in Lake Lemon sediments fall below the heavily polluted (>200 mg/kg) guidelines of EPA but two values (Sites 1 and 2) fall within the moderately polluted category (90-200 mg/kg).

4.4.2 Physical Properties

Methods

Sediment samples for particle size and percent organic matter analyses were collected in the same manner as those used for chemical analysis. Samples were placed in whirl-pac bags and stored at 4°C until analyzed. Particle size distribution was determined by the hydrometer method according to Black (1965). Percent organic matter was determined by comparing the differences between dry weights and ash weights.

Results

Results of the particle size distribution and percent organic matter analyses are given in Table 4-11. In general, clay-sized particles are more prevalent in the western part of the lake, away from the mouth of Beanblossom Creek, while sand is less prevalent. As Beanblossom Creek enters Lake Lemon, it loses much of its sediment-carrying capacity. The heaviest particles (sand) drop out first, and the lightest fraction (clay) is held in suspension until very quiet water is reached in the west end of the lake. Sample 3 has a higher value of sand and a lower value of clay-sized sediment particles than one might expect in the central lake basin. This higher sand value may likely result from the mixing of new lake sediments with sand deposits that predate the Lake Lemon materials or that may be associated with shoreline erosion. Shoreline erosion has been severe in some areas of Lake Lemon (see Section 4.4.3).

The three major sources of sediments available for deposition in Lake Lemon are till, loess, and bedrock residuum (Hartke and Hill 1974). The till, of Illinoian glacial origin, is a patchy deposit ranging from a few inches to more than ten feet in thickness. It is distributed northeast of the lake in a broad area that includes much of the upper Beanblossom Creek drainage basin. This glacial deposit probably contributes most of the clay-sized fraction carried in suspension in Beanblossom Creek. Loess deposits, which consist primarily of silt-sized sediments, are abundant on the uplands within and adjacent to the Lake Lemon drainage basin. Loess deposits average one to three feet in thickness. Weathered siltstones, which underlie all the till and loess deposits in the area, provide abundant silt-sized sediments to both Beanblossom Creek and Lake Lemon directly. The Huntington fine sandy loam is the major sand-bearing soil in the area, forming atop alluvial deposits on the Beanblossom flood plain, and presently underlies the western one-third of Lake Lemon.

TABLE 4-11. PHYSICAL CHARACTERISTICS OF LAKE LEMON'S SURFICIAL SEDIMENTS

Sample[1]	Particle Size Distribution (%)			Organic Matter (%)
	Clay	Silt	Sand	
2	33	38	29	4.3
3	15	39	46	2.3
4	19	49	32	2.3
5	9	45	46	2.2
7	23	46	31	2.7
8	12	41	47	2.4

[1]Locations illustrated in Figure 4-40.

The differential deposition of clay-, silt-, and sand-sized sediments illustrates how Lake Lemon functions as a sediment trap and that Beanblossom Creek is the major source of sediments to Lake Lemon. These observations agree with a more exhaustive survey of sedimentation in Lake Lemon which was conducted by Hartke and Hill (1974) in 1973.

The organic matter content of the surficial sediments is similar for lake and stream sites except for Lake Site 2 where percent organic matter (4.3%) is nearly double that of the others. The slower settling rate for fine organic matter could explain the greater deposits at this western lake site, similar to the mechanism for clay transport discussed above. However, a more likely cause may be related to the fact that Site 2 lies in the deepest part of Lake Lemon. The bottom waters there are not as well mixed and anaerobic decomposition of the organic matter may be slow enough to allow for greater accumulation rates.

4.4.3 Sedimentation Rate

Methods

Two north-south oriented transects (Figure 4-40) were surveyed to determine changes in sediment thickness since 1973, the year that a more complete sedimentation survey of Lake Lemon was made (see Hartke and Hill 1974). The two range lines sampled during the present study correspond to Range Lines three and eight from the 1973 survey. An assumption was made that a change in the rate of sedimentation for Range Lines 3 and 8 would be representative for the remaining range lines.

Markers delineating these range lines were placed on the north and south shores of the lake. Sampling locations were determined by use of a fixed-axis and triangulation surveying technique. An attempt was made to sample from the same locations sampled during the 1973 survey. Eleven samples were taken along Range Line (RL) 3 and ten samples along RL-8.

The bottom samples were taken with a 1.5 inch diameter piston core sampler that was pushed manually into the sediments. A 20-foot flat-bottom motor boat provided a stable but mobile work platform. Each core sample was examined immediately to determine the thickness and texture of sediment that had accumulated since the lake was impounded.

Results

Figures 4-41 and 4-42 show vertical cross sections of Lake Lemon along Range Lines 3 and 8 along with the sediment thickness determined in 1973. Results of the 1982 survey indicate that the total area of sediment along Range Line 3 is now 5.3% of the original cross-sectional area of the Lake, up from 3.0% in 1973. The sedimentation rate determined in the 1973 study (0.17% per year) would have resulted in a 51% increase or a 4.5% sediment area over the same time period. Much of the sedimentation increase noted during 1982 along Range Line 3 occurred near the northern lake shore, where visual inspection and surveying techniques indicated very active shoreline erosion - as much as three meters lost from some shoreline reaches. Given the fewer number of samples and the inability to sample from the exact same locations during the present study, applying the sedimentation rate determined in 1973 probably yields the more accurate present sediment area.

Along Range Line 8, the 1982 survey calculated a sediment area of 24.4%, a 1% increase over the 24.1% sediment area determined in 1973. Again, the 1973 sedimentation rate (0.17% per year) is probably more accurate, and applying it to 1982 yields a sediment area of 25.6% of the origianl cross-sectional area (a 6% increase at this cross section).

In summary, the less intensive 1982 sedimentation survey generally supports the sedimentation work conducted in 1973. Although the eastern end of Lake Lemon has had a greater historical loss in capacity (24.1 % in 1973) than the lake cross section represented by Range Line 3 (3% in 1973), the capacity loss rate was greater for Range Line 3 than for Range Line 8 in the eastern end of the lake during the past ten years.

Discussion

Whenever a dam is built to impound the waters of a flowing stream, the process of sediment deposition upstream of the dam begins. The usefulness of a reservoir for flood control, water

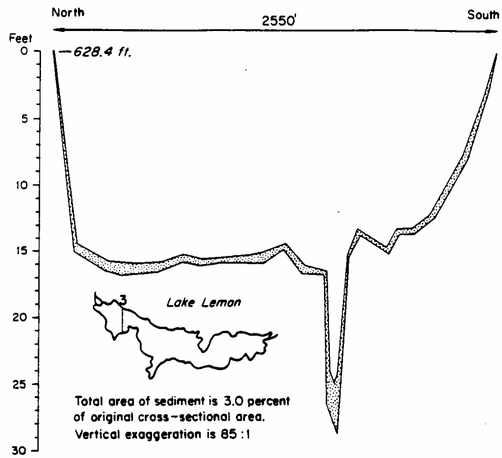


Figure 4-41. Cross section showing bottom configuration and sediment thickness for Range Line 3. From: Hartke and Hill (1973).

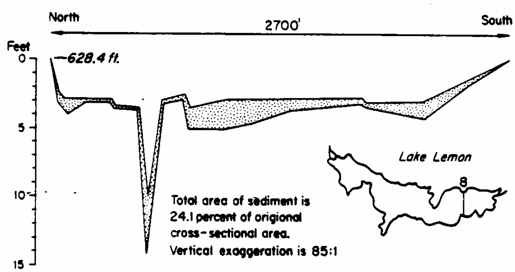


Figure 4-42. Cross section showing bottom configuration and sediment thickness for Range Line 8. From: Hartke and Hill (1973).

supply, and recreation is directly related to its capacity to hold water. As the sedimentation process continues, reservoir capacity and usefulness decreases.

Although the rate of sedimentation and capacity loss in reservoirs varies according to reservoir size, drainage basin, and other factors, it may be useful to compare sedimentation in Lake Lemon with other reservoirs. In a study of 107 Illinois reservoirs, Stall and Lee (1980) report that the median rate of capacity loss is 0.62 percent per year. A reservoir losing this capacity would have a nominal life of 161 years. Capacity loss for all 107 reservoirs studied ranged from <0.28 - 4.80 percent per year.

The overall rate of capacity loss for Lake Lemon is 0.17 percent per year (Hartke and Hill 1974). This corresponds to a nominal life of approximately 400 years. Less than ten percent of the Illinois reservoirs studied by Stall and Lee (1980) had capacity loss rates this low.

The eastern end of Lake Lemon, as represented by the Range Line 8 cross section in Figure 4-42, has a greater rate of capacity loss than the lake as a whole. The capacity loss in this portion of Lake Lemon is approximately 1.2 percent per year. This corresponds to a nominal life of about 80 years. This capacity loss rate was exceeded by only 20 percent of the Illinois reservoirs.

In their 1973 survey of Lake Lemon, Hartke and Hill (1974) estimated the volume of sediment in the lake as 615,000 m^3. Over the 20-year lifetime of Lake Lemon, this amounts to an average of 30,770 m^3/yr of sediment deposition. With an average bulk density of 0.9 g/cm^3, this volume of sediment is equivalent to 27,700 metric tonnes/yr or 1.5 metric tonnes/ha/yr (0.68 tons/acre/yr) of soil loss from the drainage basin delivered to the lake. This delivery rate is rather low compared to mean annual soil losses of 25 metric tonnes/ha/yr (11.3 tons/acre/yr) described in Wischmeier (1976) an 189 study plots in the U.S.

These results indicate that while sedimentation in Lake Lemon as a whole is not immediately threatening, the sedimentation rate in the extreme eastern end of the lake is great enough to be of concern and should therefore be managed.

4.5 BIOLOGICAL

4.5.1 Phytoplankton

Methods

Sample Collection. Samples were collected in a one liter plastic Kemmerer sampler from the sites indicated on Figure 4-1. Lake samples were collected at the surface, middle, and bottom except at Site B, where four depths were sampled. Stream samples were taken at the surface. Samples were placed in 250 ml nalgene bottles, stored on ice, and refrigerated at 4°C in the dark upon arrival at the lab. Within 48 hours of collection, the samples were preserved with Lugol's solution (1 ml per 100 ml of sample).

Concentration. Samples were mixed by gentle inversion. Each sample was then poured through a Juday plankton strainer. A small portion (approximately 5 ml) remaining in the strainer bucket contained the concentrated algae. Both the strained and concentrated portions were measured to get total volume.

The strained portion was used to rinse the storage bottle and the strainer. Distilled water was used to rinse the screen by spraying it gently. The rinse was added to the concentrate. Volume of the concentrate was adjusted by adding the strained portion until it was in a workable proportion to the total sample, (i.e. 1/10, 1/20, 1/30).

Sample Examination. Samples were examined using a Nikon inverted microscope equipped with 10X, 20X, 40X, and 100X objectives for phase magnification plus 10X oculars. One eyepiece was equipped with an unlabelled micrometer which was calibrated from a standardized stage micrometer. The other eyepiece contained an etched rectangle calibrated to be 0.38 mm wide at 200X.

Samples were mixed by inversion. Two ml were placed in a cylindrical examination cell and allowed to settle for two hours. The settling cell had a 2 ml capacity with a thin glass bottom of 500 mm^2. Diatom mounts were made prior to the count for more accurate identification (see Standard Methods, APHA 1981). Strip counts were then made at 200X. Organisms coming within the rectangle as it passed over them, or touching its right border were counted. Those touching the left border were neglected. Likewise, organisms touching the top of the strip were counted and those touching the bottom were neglected.

Organisms were classified according to genus. Each genus was counted consistantly by either filaments, colonies, or individual cells. Up to five strips were counted with the objective of obtaining at least 100 counts per sample. 400X and 1000X were available to facilitate identification. Occasionally cells, such as diatoms, were manipulated with a probe to achieve a 3-dimensional view. While viewing the settled cells, floating cells could be seen and easily brought into focus. These cells, however, were virtually nonexistant.

<u>Calculations</u>. The number of organisms per ml was calculated according to the following formula:

$$\#/\text{ml} = \frac{C \times N \times A}{L \times W \times S \times V}$$

Where:

C = concentration of the sample (generally 1/20 or 1/30)

N = number of organisms counted

A = total area of the bottom of the settling chamber ($500\ mm^2$)

L = length of a strip (19 mm)

W = width of a strip or rectangle (0.38 mm)

S = number of strips counted (1-5)

V = volume of sample settled (2 ml)

Organism dimensions were recorded periodically and these were averaged for each sampling period. Simple geometric shapes were used to approximate the volumes of each genus each month. This gave a working unit of biovolume in um^3/ml.

Results

Samples collected prior to December 1981 were examined using a different procedure by different observers. Consistancy was, therefore, impossible and these data are not included. After examining all lake and stream sites up to February 1982, Sites C and G were chosen as respresentative of the lake and streams respectively. Completed data for these locations are presented in Appendix B. Phytoplankton biovolume data for Lake Lemon are graphed in Figures 4-43 through 4-45.

Data were arranged according to the following diversions: Phylum Chlorophyta, the green algae; Phylum Cyanophyta, the blue-green algae; Sub-phylum Bacillariophyceae, the diatoms; and other, which includes Euglenophyta, Pyrrophyta, Cryptophyta, and members of Chrysophyta other than diatoms. Organisms were lumped into the "other" category because of the same number of genera in each phylum and the small number of organisms in each genus.

Diatoms showed similar seasonal trends at all three lake depths, with a peak of biovolume in December before ice formation. Their concentrations are lower under the ice but are still higher than all other algae combined. There was another diatom peak around the beginning of May, followed by a decline until late June. Summer concentrations remained high, reaching an annual maximum in early September. After this, diatom concentrations declined to a point a little below the December peak at mid-October.

Green algae had the lowest biovolume per liter of lake water of the three major categories. Their minimum concentration during the study period for all depths was in April. Their maximum for the three depths combined, was in the beginning of August, but the maximum for each depth occurred at different times: C_1 (7/21), C_2 (8/17), and C_3 (8/3).

The blue-green algae had very low concentrations in the winter months and were at their lowest (less than greens) under the ice. Their concentrations began to increase in May, but dropped again in June. After this, blue-greens dominated until mid-October when diatoms again showed the greatest biovolume. The surface concentration (C_1) maximum occurred in early September (the same

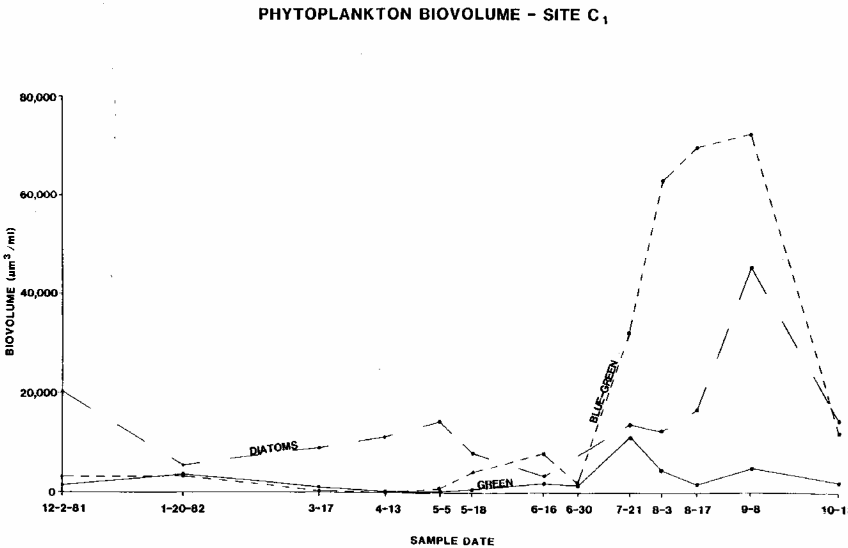


Figure 4-43. Phytoplankton biovolume data for Lake Site C_1 (surface).

PHYTOPLANKTON BIOVOLUME - SITE C_2

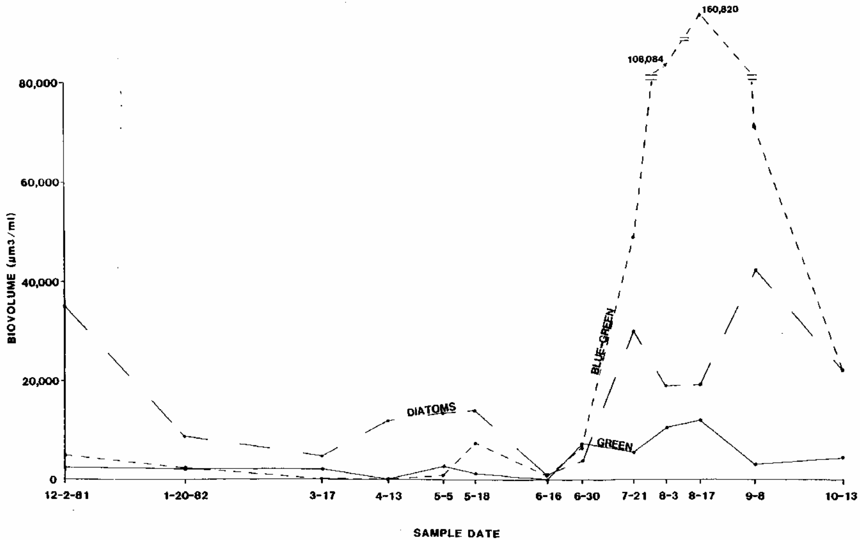


Figure 4-44. Phytoplankton biovolume data for Lake Site C_2 (mid-depth).

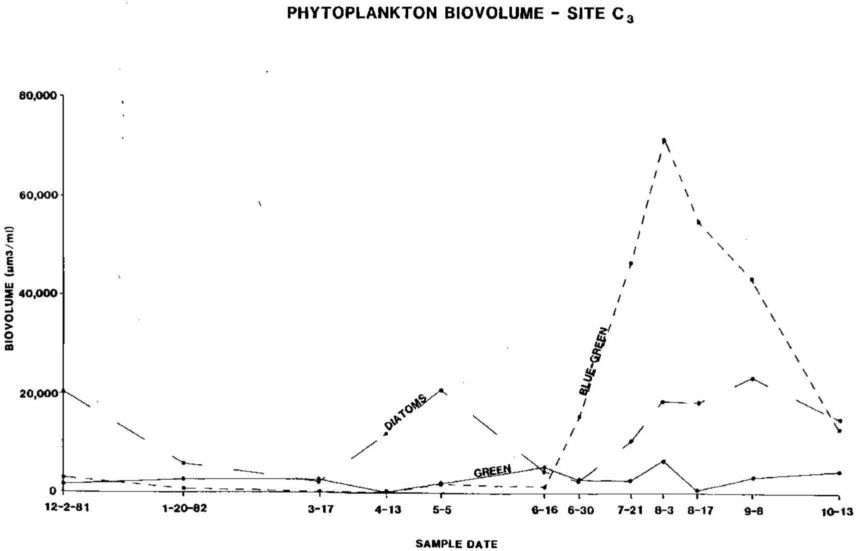


Figure 4-45. Phytoplankton biovolume data for Lake Site C_3 (bottom).

time as the diatom maximum). The maximum for Site C_2 was in mid-August, and for Site C_3 in early August.

In Beanblossom Creek at Site G, the diatoms were the most abundant phytoplankton (Figure 4-46). All categories of planktonic algae had extremely low concentrations from December until late February, at which time the diatoms were at their minimum concentration for the study period. After that, the diatoms began to increase, reaching a recorded maximum concentration at the end of June. However, the magnitude of this maximum was due to a peculiarity in our procedure. One massive filiment of Melosira made up the bulk of the biovolume. The length and diameter of this filament were unique. A low concentration occurred in August and a peak occurred in September.

Greens and blue-greens were negligible in Beanblossom Creek throughout the year except for one blue-green peak. This, too, was due to one large, unique filament of Anabaena. Figure 4-47 compares total algal biovolumes for Lake Lemon Site C and Beanblossom Creek Site G.

Seasonal Succession. Of the water quality data collected, temperature, Secchi disk transparency, and total phosphorous are the most useful in analyzing seasonal succession in phytoplankton .

The increase in light intensity in the spring is the major reason for an increase in diatoms (Moss 1972). The low concentration of diatoms under the ice is due to low light intensity and loss by sinking. Diatoms need turbulance to remain suspended (Fogg 1975). When the ice melts, high spring winds increase turbulance. As winds decrease in the summer and warmer water becomes less viscous, diatoms sink from the surface waters. Since diatoms are eurythermal (adaptable to a wide range of temperatures), competition from the stenothermal (adaptable to a specific or limited temperature range) greens and blue-greens is reduced in spring and fall (Santiago 1978; Moss 1972). Fogg (1975) states that diatoms increase with increasing concentrations of phosphorus, nitrogen, and silicon. In Lake Lemon, a drop in diatom concentration coincided with a drop in total phosphorus (TP) in

PHYTOPLANKTON BIOVOLUME - SITE G

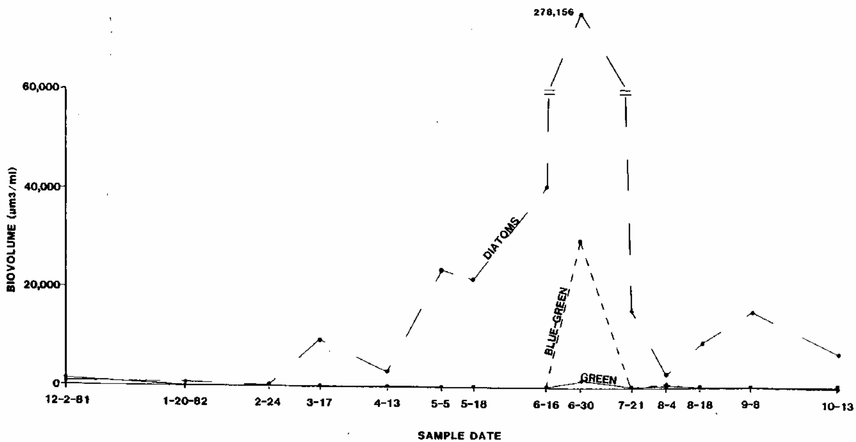


Figure 4-46. Phytoplankton biovolume data for Beanblossom Creek Site G.

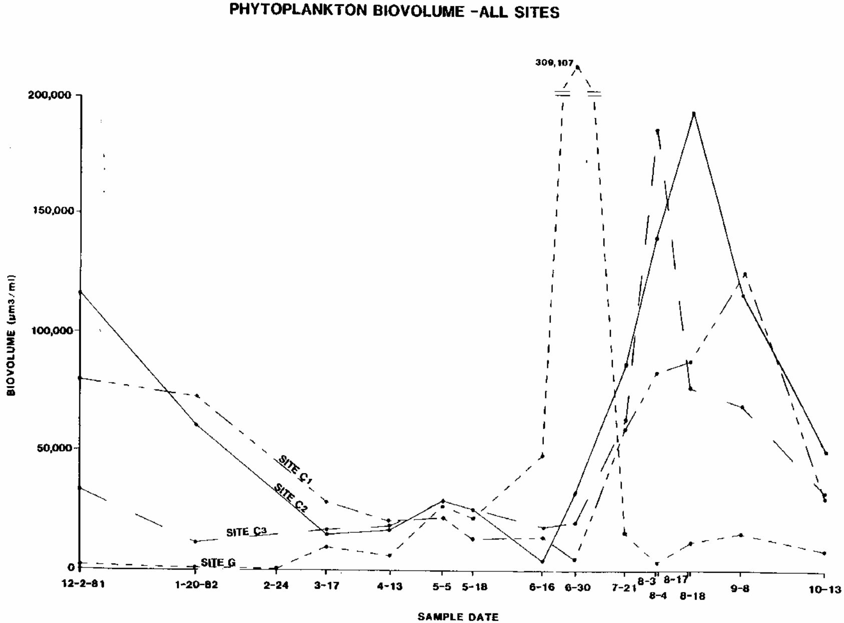


Figure 4-47. Comparison of total phytoplankton biovolume data for Lake Lemon Site C and Beanblossom Creek Site G.

June. Round showed that a species of Synedra (the most abundant genus of diatom in Lake Lemon) grew best with a spring/fall photo period of 8-12 hours. This coincides with observed spring and fall diatom peaks in Lake Lemon.

Green algae have an optimum temperature range from 20 - 25°C (Round 1968). Round also states that higher temperatures induce germination of the spores of some greens and blue-greens. The maximum concentration of green algae in Lake Lemon coincided with the maximum summer temperatures. However, those maximum temperatures were slightly above the stated optimum (27 - 28°C). Fogg (1975) states that the green algae tend to thrive during the summer, as nutrients become depleted. This is partially due to their ability to accumulate excess nutrients. When TP is at the lowest concentration, the green algae are on an increase although their maximum concentration coincides with a high TP concentration. As temperatures decrease so does the concentration of greens.

Like the greens, blue-green algae have a high temperature optimum and are capable of withstanding higher temperatures (Fogg 1975). In Lake Lemon, the maximum blue-green concentration and maximum water temperature occur at the same time. Blue-greens can be successful even when nutrient concentrations are low, because they can accumulate and store excess nutrients (Fogg 1975; Santiago 1978). This agrees with the observation that blue-green concentrations began to increase when TP concentrations were low in late June. Some blue-greens have the added advantages of buoyancy (Fogg 1975) and nitrogen fixation (Santiago 1978). These traits are found in Lake Lemon's two most abundant genera, Anabaena and Anabaenopsis. In October, the blue-greens give way to the diatoms. This is due primarily to the drop in temperature as stated above.

The stream data are more difficult to analyze. All three categories of algae reach maximum concentrations at the same time in late June. This coincided with a total phosphorus peak. The stream temperatures averaged several degrees cooler than the lake which would favor the diatoms and stream turbulance would diminish the mobility or buoyancy advantage held by greens and blue-greens.

Discussion

From our observations of Sites C and G it would appear that Lake Lemon does not have an algae problem. The lake and stream concentrations of algae are low. Nearby Lake Monroe, for example, has an algal biovolume about one order of magnitude greater than Lake Lemon (Santiago 1978). No blooms have been reported and there are no problems with odor or excess oxygen demand in Lake Lemon. The shading effect of the highly turbid water in Lake Lemon may reduce light transmittance sufficiently enough to reduce phytoplankton productivity. If steps are taken to control turbidity without lowering nutrients, algal blooms might be expected.

4.5.2 Macrophytes

Procedure

On two separate occasions, three-day sampling trips were conducted, covering approximately one third of the lake each day. The first occurred in late spring (1982) nearly one week after the herbicide, Hydrothal 191, was applied. The second survey was made in late summer, 1982. The survey followed the shoreline since all macrophytes were in water less than 3.5 m (10 ft) deep.

Samples were taken of every species observed using a long-handled rake and a dip net. The entire plant was removed if possible. When necessary, plants were uprooted by hand. Flowering specimens were especially sought. The extent and depth range of all species were mapped. Samples were kept in five gallon buckets allowing the emergent portions of the plants to remain dry.

All specimens were keyed out the day they were collected. Flowers were necessary to accurately key to species. Identification keys used were: Muenscher (1944) and Britton and Brown (1970).

Results

The following were found on both sampling trips:

Justicia (Dianthera) americana

Dense-flowered water willow

Myriophyllum _spicatum_ (Figure 4-48)
Eurasian water milfoil

Nuphar _advena_
Yellow water lily

Rumex _verticillatus_
Swamp dock

Typha spp.
Cattails

The map (Figure 4-49) showing the extent of the macrophytes was overlain with a grid to determine that the approximate extent of _Myriophyllum_ was 91 ha (225 acres). _Myriophyllum_ was found between 0.75 to three meters deep (2.5 - 10 ft) and nearly surrounded the lake. The shallow eastern lobe was nearly covered with this species. _Justicia_ grew from 0.6m (2 ft) of water to the high water line whenever rock rip-rap was not used along the shore. It too was very extensive. _Nuphar_ was scarce outside of the eastern lobe where it was common but not extensive. _Rumex_ was uncommon throughout the lake. _Typha_ was found only at stream inlets and in the eastern lobe. There it was extensive but only in less than 0.6m of water.

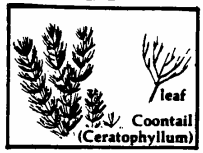
Discussion

Justicia _americana_ does not appear to be a problem in any way. In fact, it seems to maintain shore stability and prevent erosion. One can easily observe the frequent movement of fish through this emergent plant so it would also seem to serve as fish habitat. The needs of this plant are important as food for birds (McAtee 1939). We therefore conclude that the _Justicia_ is a desirable plant and should remain at its current levels.

Myriophyllum _spicatum_ is a nuisance plant to boaters because it fouls boat propellers and can get tangled around the arms and legs of swimmers. Bass fisherman prefer this plant, however; because it serves as habitat for fish. The seeds serve as food for waterfowl (McAtee 1939). The dense growths of _Myriophyllum_ in the eastern

Eurasian water milfoil
(Myriophyllum spicatum)

Plant entirely or almost entirely below water surface.
Plant may be less than one foot tall or up to 15 feet tall.
Color usually grass green. Stems or tips may be reddish.
Each leaf feather-like; leaves 4 to a whorl on the stem.
Leaves small, 1" x 3/4".



Note: Two other plants are sometimes mistaken for Eurasian milfoil. One of these is a native milfoil (Myriophyllum exalbesceus), and the other is called Coontail (Ceratophyllum). Both are pictured here for comparison. Note that the native milfoil has fewer pairs (usually less than 12) of leaflets on each feather-like leaf. The Coontail does not have a feather-like leaf.

Figure 4-48. Illustration and description of Eurasian water milfoil (Myriophyllum spicatum). Source: METRO (undated).

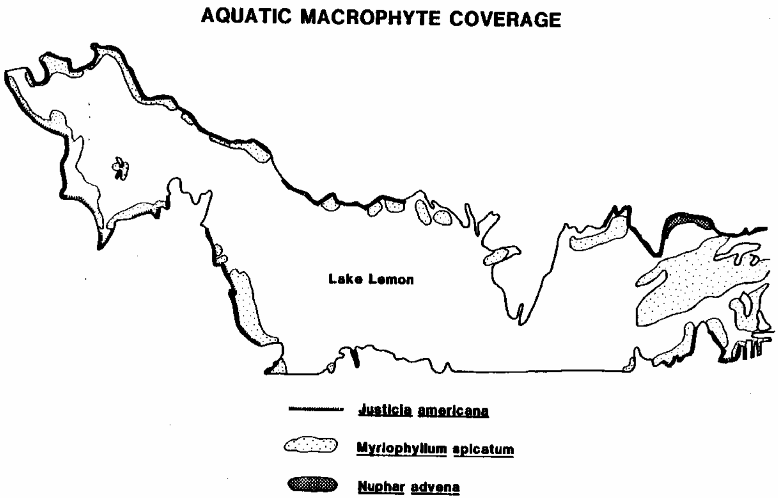


Figure 4-49. Extent of major aquatic macrophytes inhabiting Lake Lemon.

lobe may help in filtering out some of the incoming sediment load. However, M. spicatum acts as a nutrient pump, drawing phosphorus and nitrogen from the sediments and releasing these nutrients during senescence and sloughing of leaves (Grace and Wetzel 1978; Barko and Smart 1979). Nichols (1971) states that maximum biomass of this plant occurs just before flowering. Immediately after flowering, decomposition begins. Approximately 70 percent of the phosphorous and 50 percent of the nitrogen from the plant tissue are released to the water at this time (Mitchell 1974). In Lake Monroe, Landers and Frey (1980) found that M. spicatum senescence accounted for as much as 20 percent of the annual phosphorous budget and 2.2 percent of the annual nitrogen budget for the lake.

Regrowth from the established roots requires the accumulation of total nonstructural carbohydrate (TNC) (Titus 1977). Storage of TNC occurs in September and October.

Nuphar advena is found in such low densities that it does not present a problem. Birds use its flowers, seeds, and leaves and muskrats use the rhizomes as food (Mitchell 1974).

Rumex verticillatus was found only in very shallow water or just above the high water line. It occurred in few locations in low densities. Its seeds are a valuable food source for waterfowl, especially mallards (Mitchell 1974; McAtee 1939)

Typha has been known to invade the shallows during summer drawdown but can be controlled by cutting below the water line. The dense stands existing in the eastern lobe of Lake Lemon provide excellent cover and habitat for many animals (Mitchell 1974). The roots and leaves are eaten by wild geese (McAtee 1939).

4.5.3 Fish

Methods

The fishes of Lake Lemon were surveyed by the Indiana Department of Natural Resources from September 27 through October 1, 1982. Fish were collected through the use of day and night shocking, gill nets, and trap nets. Shocking was done in the littoral areas (<1.5 m). Trap nets were placed perpendicular to the shoreline at various depths. Gill nets were used at depths between 2 m and 4.5 m. The dimensions of the gill nets were 76m (250 ft) long and 1.8m (6 ft) deep, made up of five 15-m* (50 ft) panels, each with a different mesh size: 1.91 cm (3/4 in.), 2.54 cm (1 in.), 3.18 cm (1 1/4 in.), 3.81 cm. (1 1/2 in.) and 5.08 cm (2 in.). Nets were left in place for approximately 24 hours. The fish collected from all three methods were counted according to species, and their lengths and weights were recorded.

Results

In their preliminary report, the Indiana DNR described the lake in terms of its capacity as a sport fishery. Nearly half of the fish collected were gizzard shad, Dorosoma cepedianum, 80% of which were small enough (<7 inches (17.78 cm) to be utilized as a food source for the larger piscivores (see Table 4-12). Bluegill, Lepomis macrochirus, were the second most abundant species (19.8% by number) although they were all less than 6.5 inches (16.5 cm) in length. White crappie, Pomoxis annularis, exhibited a similarly stunted population but some larger specimens, reaching 11.5 inches (29.2 cm) long, were collected.

The largemouth bass, Micropterus salmoides, population was described as being much better than those of other area lakes. More than 20% of these fish were found to be greater in length than the 14 inch (35.6 cm) size limit for this species. In their 1979 survey of nearby Lake Monroe, the DNR found only 6.4% of the bass exceeding this limit. This species showed a fairly even distribution throughout the observed size range -- from three inches to 19 inches (7.6 cm to 48.3 cm). This would indicate that not only is there good representation in the immature year classes, promising that short-term harvests will remain good, but also in the large breeding stock for the long-term success of the population.

The channel catfish, Ictalurus punctatus, population was also described as being good. Their large and evenly distributed size range (7.5 - 26 inches or 19.1 - 66.0 cm) indicated a successful future for this species as well.

Two other notable species were the golden redhorse, Moxostoma erythrurum, and the carp, Cyprinus carpio. Together they constituted only 7.6% of the total number of fish collected, but by weight, they made up nearly 45%.

TABLE 4-12. FISH SPECIES AND RELATIVE ABUNDANCE BY NUMBER AND WEIGHT OF SPECIMENS COLLECTED DURING THE LAKE LEMON FISH SURVEY.

COMMON NAME	SCIENTIFIC NAME	NUMBER	(%)	WEIGHT (LBS.)	(%)
Gizzard shad	Dorosoma cepedianum	1,479	48.5	135.87	17.7
Bluegill	Lepomis macrochirus	604	19.8	50.99	6.7
White crappie	Pomoxis annularis	249	8.2	18.57	2.4
Golden Redhorse	Moxostoma erythrurum	198	6.5	200.90	26.2
Largemouth bass	Micropterus salmoides	154	5.1	114.61	15.0
Yellow bass	Morone mississippiensis	91	3.0	8.94	1.2
Channel catfish	Ictalurus punctatus	65	2.1	59.94	7.8
Redear sunfish	Cepomis microlophus	46	1.5	6.96	0.9
Spotted bass	Micropterus punctalatus	34	1.1	9.89	1.3
Carp	Cyprinus carpio	33	1.1	138.15	18.0
Yellow perch	Perca flavescens	28	0.9	1.62	0.2
Golden shiner	Notemigonus crysoleucas	14	0.5	1.93	0.3
Logperch	Percina caprodes	14	0.5	0.67	0.1
Warmouth	Lepomis gulosis	13	0.4	1.38	0.2
Flathead	Pylodictis olivaris	10	0.3	7.49	1.0
Brook silverside	Labidesthes sicculus	7	0.2	0.05	*
Spotted sucker	Minytrema melanops	3	0.1	4.97	0.6
White sucker	Catostomus commersoni	3	0.1	3.08	0.4
Spotfish	Notropis spilopterus	3	0.1	Trace	*
Yellow bullhead	Ictalurus natalis	1	*	0.35	*
Totals		3,049		766.36	

*Less than 0.1 percent.

The ages of the fish surveyed in Lake Lemon were evaluated by comparing them to lenth-age averages for surrounding lakes. For example, four-year old bluegill in Lake Lemon were 5-6 inches long. On the average, a four-year old bluegill in South-Central Indiana are six inches long. Therefore, growth of these larger Lake Lemon bluegill was lightly below average. Growth of small bluegill was average. Gizzard shad and crappie were slow growing in Lake Lemon. Growth of largemouth bass over nine inches long was above average while growth of smaller bass was at or below average. Redear sunfish and yellow perch growth was slightly below average.

The complete preliminary Indiana DNR fisheries report, including all the data, is presented in Appendix C.

<u>Management</u>

Two management techniques useful in controlling aquatic macrophytes, may also be useful in managing fisheries. These are machrophyte harvesting and lake drawdown. Breck and Kitchell (1979) use their bioenergetics model for bluegill to support the hypothesis that harvesting macrophytes leads to fewer but larger fish of this type. Reduced cover leads to increased predation on small fish resulting in a reduction of young of the year (YOY) densities. This, in turn, leads to reduced feeding pressure on zooplankton. Bartell and Breck (1979) discuss how this process can cause an increase in mean zooplankton size and thereby cause a decrease in mean phytoplankton size.

Lake level drawdown would concentrate the fishes into a smaller volume of water. This would also increase predation pressure on the smaller fish, thus providing better growth opportunities for the larger prey species (Beard 1973).

There are two possible negative aspects associated with both techniques. First, algal blooms could arise from reduced competition for nutrients and light once macrophytes are removed. Second, organisms which serve as a food source for fish could be lost through the loss of aquatic macrophyte habitat. Will et al. (1978) suggest that this impact on fish would be slight.

4.6 ON-SITE WASTEWATER TREATMENT SYSTEMS

4.6.1 Overview

Historical accounts and public opinion have suggested that on-site wastewater treatment systems (septic tanks and soil adsorption fields) are an important source of nutrients to Lake Lemon. To help answer this question, we initiated a two-phased approach that included: 1) a questionnaire sent to all residents living on the immediate shoreline of Lake Lemon or along lower Beanblossom Creek, and 2) direct measurement of Lake Lemon's shoreline to detect plumes originating from on-site wastewater treatment systems.

4.6.2 Survey Questionnaires

Method

Questionnaires were mailed to 330 property owners of Lake Lemon lakeshore private residences and commercial establishments. They were also hand-distributed to 32 private residences on Beanblossom Creek near the east end of Lake Lemon. Respondents were asked to return by mail the completed questionnaire. Following the return due date, a door-to-door survey of areas with a low response rate was conducted. Additional questionnaires were distributed as necessary.

Missing Information

Many questionnaires were incompletely filled out because the respondent did not know the required information or chose not to answer the question. For those questions with more than one answer, the number of replies is indicated. In some cases (such as the incidence of septic system problems) the low rate of response may have biased the results if a disproportionately high number of residents with negative responses replied.

Response Analysis

Respondents returned 132 of the 374 distributed questionnaires (35%). Three of the returned questionnaires were not completed and thus not included in the response analysis.

The responses were divided among the four distinct regions (North Shore, South Shore, Chitwood Addition and Beanblossom Creek) for the purpose of comparison (see Figure 4-50). Responses were also totaled for the lake as a whole. Percentages were calculated from the number of responses to a particular question.

Results

The results of this survey are discussed below and in Table 4-13.

Year-Round vs. Seasonal (see Question 3). According to the survey returns, 59% of the lake residents are seasonal, i.e. they live at the lake less than ten months/year. This is probably a conservative figure since a disproportionately large number of year-round residents were contacted during the door to door surveying period and because year-round residents were more willing to participate in the survey.

AGGREGATION REGIONS FOR QUESTIONNAIRE RESULTS

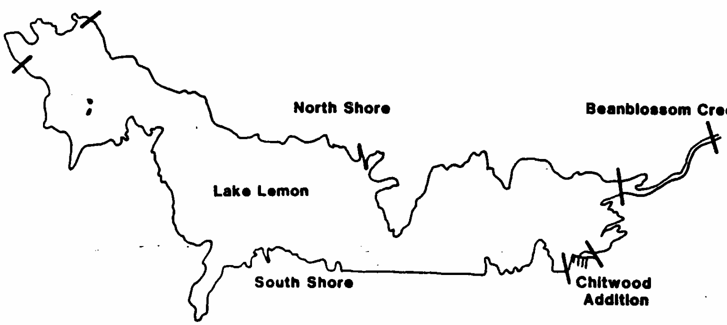


Figure 4-50. Map of the four lake areas aggregated for questionnaire analysis.

TABLE 4-13. QUESTIONNAIRE REPLIES

	Percentage Responses (number of replies is in parentheses)				
	North Shore	South Shore	Chitwood Addition	Beanblossom Creek	Total[1]
QUESTION 1					
Lake frontage:					
a. yes	82 (45)	83 (40)	88 (7)	100 (7)	84 (101)
b. no	18 (10)	17 (8)	12 (1)	0	16 (19)
QUESTION 2					
How long have you lived on the lake?					
a. 0-5 yrs.	21 (13)	33 (16)	43 (3)	43 (3)	27 (35)
b. 6-10 yrs.	27 (17)	12 (6)	29 (2)	29 (2)	22 (29)
c. 10-15 yrs.	16 (10)	17 (8)	14 (1)	0	15 (19)
d. more than 15 yrs.	37 (23)	38 (18)	14 (1)	29 (2)	36 (46)
QUESTION 3					
Are you a year-round or seasonal resident?					
a. year-round (10 mo. or more)	40 (25)	42 (21)	25 (2)	71 (5)	41 (54)
b. seasonal (less than 10 mo.)	60 (38)	58 (29)	75 (6)	29 (2)	59 (78)
QUESTION 4 (For year-round residents only)					
Part A.					
How many residents live here year-round?					
a. 1-2	78 (18)	76 (13)	100 (2)	50 (2)	77 (36)
b. 3-4	17 (4)	18 (3)	0	25 (1)	17 (8)
c. 5-6	4 (1)	0	0	0	2 (1)
d. 7-9	0	6 (1)	0	25 (1)	4 (2)
e. 10 or more	0	0	0	0	0
Part B					
Does this number increase during the year					
a. yes	57 (13)	39 (7)	50 (1)	25 (1)	47 (22)
b. no	43 (10)	61 (11)	50 (1)	75 (3)	53 (25)
Part C					
For how long?					
a. 5-9 mo.	0	0	0	0	0
b. 3-4 mo.	0	0	0	0	0
c. 4-8 wk.	9 (2)	6 (1)	0	25 (1)	7 (4)
d. 1-4 wk.	0	6 (1)	0	0	2 (1)
e. weekends	48 (11)	28 (5)	50 (1)	0	38 (21)
QUESTION 5 (for seasonal residents only)					
Part A.					
During what seasons so people reside here?					
a. spring	74 (28)	62 (18)	100 (4)	100 (2)	68 (52)
b. summer	100 (38)	100 (29)	100 (4)	100 (2)	100 (76)
c. fall	66 (25)	48 (14)	75 (3)	100 (2)	58 (44)
d. winter	13 (5)	14 (4)	25 (1)	0 (2)	13 (10)
Part B					
For how long?					
a. 5-9 mo.	19 (7)	24 (7)	0	50 (1)	20 (15)
b. 3-4 mo.	11 (4)	17 (5)	0	0	13 (10)
c. 4-8 wk.	14 (5)	7 (2)	20 (1)	0	11 (8)
d. 1-4 wk.	22 (8)	17 (5)	20 (1)	50 (1)	20 (15)
e. weekends	35 (13)	34 (10)	60 (3)	0	37 (28)
Part C					
What is the average number of people who live here on a seasonal basis?					
a. 1-2	32 (11)	48 (11)	33 (2)	50 (1)	40 (27)
b. 3-4	53 (18)	35 (8)	50 (3)	50 (1)	46 (31)
c. 5-6	15 (5)	17 (4)	17 (1)	0	15 (10)
d. 7-9	0	0		0	0
e. 10 or more	0	0		0	0

TABLE 4-13 CONTINUED

	North Shore	South Shore	Chitwood Addition	Beanblossom Creek	Total[1]
Part D					
Do you have plans to move here permanently?					
a. yes	24 (8)	15 (4)	0	0	17 (12)
b. no	76 (26)	85 (22)	100 (5)	100 (2)	83 (58)
QUESTION 6[2]					
The following list presents typical problems associated with recreational lakes. Indicate which of the problems you consider to be more important on Lake Lemon by ranking them 1, 2,...etc, with 1 being the most important. Leave blank the items which you do not consider to be a problem.					
a. lake filling	60 (36)	60 (29)	100 (8)	100 (7)	65 (82)
b. human wastes from septic tanks	23 (14)	35 (17)	38 (3)	29 (2)	29 (37)
c. bad odors	8 (5)	13 (6)	0	0	9 (37)
d. shore erosion	55 (33)	69 (33)	50 (4)	14 (1)	59 (75)
e. public use/abuse by non-residents	33 (20)	23 (1)	13 (1)	43 (3)	29 (37)
f. algal blooms	40 (24)	31 (15)	38 (3)	57 (4)	37 (47)
g. exposed (emergent) aquatic plants	25 (15)	27 (13)	50 (4)	43 (3)	29 (37)
h. submerged aquatic plants	85 (51)	81 (39)	75 (6)	86 (6)	82 (104)
Number of Replies	60	48	8	7	127
QUESTION 7					
Since you have lived on the lake have you noticed that the condition of Lake Lemon has:					
a. improved	22 (13)	31 (14)	29 (2)	0	24 (29)
b. remained about the same	38 (17)	40 (18)	29 (2)	0	31 (38)
c. gotten worse	50 (30)	29 (13)	43 (3)	100 (7)	45 (55)
QUESTION 8					
In which of the following uses of Lake Lemon do you participate?					
a. swimming	82 (51)	71 (34)	50 (4)	43 (3)	74 (95)
b. power boating	82 (51)	79 (38)	63 (5)	43 (3)	78 (100)
c. canoeing/sailing	31 (19)	42 (20)	13 (1)	0	31 (40)
d. fishing	76 (47)	79 (38)	75 (6)	100 (7)	77 (99)
e. observing wildlife	63 (39)	73 (35)	50 (4)	71 (5)	65 (84)
f observing the beauty of the lake itself	85 (53)	94 (45)	63 (5)	43 (3)	83 (107)
Number of replies	62	48	8	7	129
QUESTION 9					
In your opinion, which, if any, of the listed uses have been adversely affected by deterioration of the water quality of Lake Lemon?					
a. swimming	56 (35)	65 (31)	50 (4)	14 (1)	57 (73)
b. power boating	53 (33)	46 (22)	38 (3)	57 (4)	49 (63)
c. canoeing/sailing	13 (8)	15 (7)	0	0	12 (15)
d. fishing	31 (19)	25 (12)	38 (3)	57 (4)	29 (38)
e. observing wildlife	3 (2)	6 (3)	0	14 (1)	5 (6)
f. observing the beauty of the lake	39 (24)	33 (16)	13 (1)	29 (2)	33 (43)
Number of replies	62	48	8	7	129
QUESTION 10					
List number of water using fixtures on your property. (Responses show the percentage of respondents indicating one or more of the particular fixture).					
a. showers/bathtubs	95 (56)	94 (46)	88 (7)	83 (5)	94 (17)
b. sinks	95 (56)	96 (47)	100 (6)	100 (6)	96 (120)
c. toilets	95 (56)	92 (45)	100 (8)	100 (6)	94 (118)
d. clothes washing machine	42 (25)	39 (19)	25 (2)	50 (3)	39 (49)
e. dishwasher	20 (12)	20 (10)	13 (1)	0	18 (23)
f. garbage disposal	15 (9)	19 (14)	13 (1)	17 (1)	20 (25)
g. water softener	3 (2)	4 (2)	0	0	3 (4)
Number of replies	59	49	8	6	125

TABLE 4-13 CONTINUED

	North Shore	South Shore	Chitwood Addition	Beanblossom Creek	Total[1]
QUESTION 11					
Approximate monthly water bill					
a. $1-$6	0	51 (20)	0	0	
b. $7-$12	59 (29)	31 (12)	67 (2)	50 (2)	
c. $13-$18	22 (11)	10 (4)	33 (1)	0	
d. $19 or more	18 (9)	8 (3)	0	50 (2)	
Minimum water bill	$11.40	$5.50	$11.40	$11.40	
QUESTION 12					
Part A.					
Do you fertilize your lawn?					
a. yes	30 (18)	15 (7)	38 (3)	17 (1)	24 (30)
b. no	70 (43)	85 (41)	63 (5)	83 (5)	76 (96)
Part A					
How many times a year?					
a. 1	20 (12)	8 (4)	13 (1)	17 (1)	15 (19)
b. 2-3	10 (6)	6 (3)	25 (2)	0	9 (11)
QUESTION 13					
Part A					
Do you water your lawn?					
a. yes	12 (7)	6 (3)	14 (1)	0	10 (12)
b. no	88 (52)	94 (46)	86 (6)	100 (6)	90 (111)
Part B					
How often?					
a. more than once a week	5 (3)	0	0	0	2 (3)
b. less than once a week	7 (4)	6 (3)	14 (1)	0	7 (9)
QUESTION 14					
Drinking water source:					
a. rural water association	83 (50)	92 (44)	38 (3)	50 (3)	82 (102)
b. on-lot well	5 (3)	4 (2)	50 (4)	50 (3)	10 (12)
c. Lake Lemon	5 (3)	0	0	0	2 (3)
d. imported water purchased from a local hauler or carried in	7 (4)	4 (2)	12 (1)	0	6 (7)
QUESTION 15					
How many bedrooms does this house have?					
a. 1	16 (10)	6 (3)	63 (5)	33 (2)	17 (22)
b. 2	41 (25)	53 (25)	25 (2)	50 (3)	45 (57)
c. 3	30 (18)	28 (13)	13 (1)	17 (1)	26 (33)
d. 4	10 (6)	11 (5)	0	0	9 (11)
e. 5	3 (2)	2 (1)	0	0	2 (3)
QUESTION 16					
What is the age of this house?					
a. 0-5 yrs.	2 (1)	10 (5)	0	0	5 (6)
b. 6-10 yrs.	15 (9)	2 (1)	13 (1)	0	9 (11)
c. 11-15 yrs.	23 (14)	25 (12)	0	50 (3)	23 (29)
d. more than 15 yrs.	57 (35)	56 (27)	75 (6)	50 (3)	59 (75)
e. unknown	3 (2)	6 (3)	13 (3)	0	5 (6)
QUESTION 17					
Have you stabilized your shoreline to minimize bank erosion?					
a. yes	93 (53)	89 (34)	88 (7)	80 (4)	91 (102)
b. no	7 (4)	11 (4)	12 (1)	20 (1)	9 (10)
QUESTION 18					
What type of wastewater disposal system does this house have?					
On-Site					
a. septic tank	91 (56)	84 (42)	100 (7)	100 (7)	87 (112)
b. drainfield (soil absorption field)	38 (23)	34 (17)	0	14 (1)	31 (40)
c. cesspool (dry well)	2 (1)	12 (6)	0	0	5 (7)
Off-Site					
d. holding tank	0	10 (5)	0	0	5 (6)
Unknown	3 (2)	2 (1)	0	0	2 (3)
None	3 (2)	0	0	0	2 (2)
Number of replies	61	50	7	7	129

TABLE 4-13 CONTINUED

	North Shore	South Shore	Chitwood Addition	Beanblossom Creek	Total[1]
QUESTION 19					
What is the age of the present waste disposal system?					
a. 0-5 yrs.	11 (6)	24 (12)	29 (2)	29 (2)	19 (23)
b. 6-10 yrs.	27 (15)	12 (6)	0	29 (2)	20 (24)
c. 11-15 yrs.	14 (8)	10 (10)	0	14 (1)	15 (19)
d. more than 15 yrs.	34 (19)	37 (18)	29 (2)	29 (2)	35 (43)
e. unknown	14 (8)	6 (3)	43 (3)	0	11 (14)
QUESTION 20					
Have you ever noticed problems with other Lake Lemon residents' wastewater disposal systems?					
a. yes	27 (13)	48 (20)	14 (1)	17 (1)	33 (35)
b. no	73 (36)	52 (22)	86 (6)	83 (5)	67 (72)
QUESTION 21					
(For those residents with on-site wastewater disposal)					
Part A.					
Have <u>you</u> ever had problems with <u>your</u> septic system such as backups, ponding, odors, etc.?					
a. yes	18 (9)	39 (16)	14 (1)	20 (1)	25 (27)
b. no	82 (42)	61 (25)	86 (6)	80 (4)	75 (80)
Part B					
Has your septic sytem ever been inspected for pumping or maintenance?					
a. yes	65 (35)	51 (20)	50 (4)	80 (4)	60 (64)
b. no.	35 (19)	49 (19)	50 (4)	20 (1)	40 (43)
Part C					
Has your septic system ever been repaired or enlarged?					
a. Yes	19 (10)	38 (15)	0	33 (2)	26 (28)
b. no	81 (44)	62 (24)	100 (7)	67 (4)	74 (81)

[1]The responses of 4 questionnaires of unknown lake address have been included in the total

[2]See discussion section on lake quality for information on data tabulation.

Lake Quality Problems (see Question 6). Respondents were asked to rank by importance a list of possible lake problems. The overall rank of each problem was established by listing the top four ranked problems from each questionnaire and then determining the frequency with which each was mentioned.

In summary, the lake residents perceive the lake's most important problems to be: submerged aquatic plants (82%), lake filling (65%), shoreline erosion (59%), and algal blooms (37%). In each of the four regions submerged aquatic plants rank as either the first or second most significant problem.

Among South Shore residents the ranking differed in that the top four problems consisted of: submerged aquatic plants (81%), shoreline erosion (69%), lake filling (60%) and human wastes from septic tanks (35%). This reflects the South Shore residents' concern over shoreline erosion on the city property along the South Shore and the increased incidence of septic system problems along the South Shore (see Questions 20 and 21). More people (13%) reported odor problems in this area.

At the eastern end of the lake, lake filling is viewed as the most important problem by all of the Chitwood Addition and Beanblossom Creek residents. Both areas also placed submerged aquatic plants in the second position. The third and fourth positions were filled by a tie between shoreline erosion (50%) and exposed aquatic plants (50%) in Chitwood Addition. Algal blooms (57%) are the number three problem along Beanblossom Creek followed by a tie between exposed aquatic plants (43%) and public use/abuse by non-residents (43%).

Several residents (4%) commented on problems with the regulation of the lake's water level. Most felt the water level gets too low in late summer to allow them full usage of the lake. This response is probably conservative because regulation of the lake's water level was not listed as a possible problem.

Lake Condition (see Question 7). Over the entire lake 45% of the residents feel the lake's condition has gotten worse since they have lived on the lake, 31% feel it has stayed the same, and 24%

feel it has improved. Responses varied widely among the four regions.

All of the Beanblossom Creek residents feel the lake's condition has gotten worse compared to 50% of the North Shore residents, 43% of the Chitwood Addition residents and 29% of the South Shore residents. This can perhaps be explained by the fact that Beanblossom Creek residents consider lake filling to be the most important lake problem and it is not being controlled. Residents of the North Shore and Chitwood Addition also see lake filling as one of the two most important problems. However, South Shore residents rank lake filling below submerged aquatic plants and shore erosion. Both of these problems are being addressed to some extent by chemical treatments in the first case and shore stabilization in the second.

Over half of the residents who have lived on the lake more than five years feel the lake's condition has gotten worse (see Figure 4-51). This is most noticeable among those who have lived on the lake 10 - 15 years where 72% feel the lake's condition has gotten worse. More residents (32%) who have lived on the lake less than five years believe its condition has improved than residents in any other category. This seems to reflect the profuse growth of nuisance aquatic plants approximately five years ago and the subsequent chemical treatments for nuisance aquatic plants during the past four years. Half of those who have lived on the lake less than five years have seen no change in the lake's condition.

<u>Lake Uses (see Question 8)</u>. The most popular lake uses are: observing the beauty of the lake (82%), power boating (77%), fishing (76%), and swimming (73%).

An overwhelming 94% of the South Shore residents enjoy observing the lake's beauty in contrast to 43% of the Beanblossom Creek residents (who can't see the lake from their homes). Approximately 80% of the North and South Shore residents participate in motor boating but only 63% of the Chitwood Addition residents and 43% of the Beanblossom Creek residents. The lower participation in power boating at the east end of the lake could be due to the difficulty of maneuvering a motor boat through the shallow water. All of the

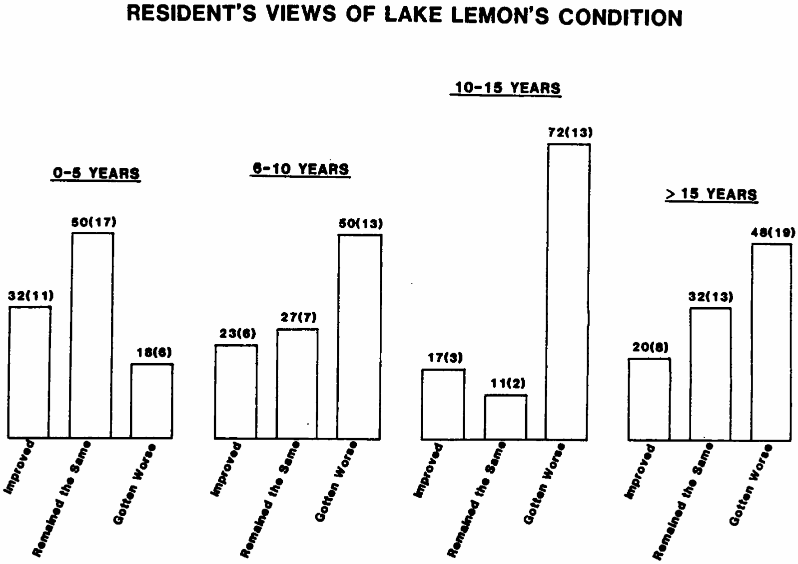


Figure 4-51. Resident's views of Lake Lemon's condition as a function of number of years of residency. Category percent and number of respondents are given for each column.

Beanblossom Creek residents reportedly fish, as well as about 75% of the residents in the other regions. Swimming is enjoyed by about 80% of the North and South Shore residents and less than half of the Chitwood Addition and Beanblossom Creek residents. This might be explained by the high turbidity and stagnation of the water as well as the submerged aquatic plants in the Chitwood Addition and Beanblossom Creek areas.

Almost two-thirds of the total respondents indicated that they enjoy observing wildlife in the area. Canoeing and/or sailing are lake uses in which 31% of the total residents participate. Other lake uses mentioned were ice skating (3%) and water skiing (3%). The figures for ice skating and waterskiing are probably low because they were not listed as possible lake uses.

Adversely Affected Lake Uses(see Question 9). Swimming and motor boating are the two activities which the lake residents feel have been most negatively impacted by a deterioration in the water quality of Lake Lemon. A smaller percentage of Beanblossom Creek residents feel the lake's swimming value has declined. The most commonly listed factor adversely affecting these two uses was the profuse growth of submerged aquatic plants.

A third of the lake residents feel the lake's beauty has diminished. This ranged from a high of 39% among North Shore residents to a low of 13% among Chitwood Addition residents. Fishing on the lake has deteriorated according to 29% of the replies. This is most significant in the Beanblossom Creek area where 57% feel fishing has gotten worse.

Other uses which residents feel have been adversely affected by deterioration of the lake's water quality include: canoeing and/or sailing, observing wildlife, and water skiing.

House and Wastewater Disposal System Age (see Question 16 and 19). 82% of the lakeshore housing development occurred previous to 1971. Since only half of the wastewater disposal systems are 11 or more years old, some of the older systems have obviously been replaced.

Wastewater Disposal Systems (see Question 18). Most of the lake residents utilize a septic tank for wastewater disposal. The number of residents using drainfields (soil adsorption fields) is probably low because many septic tank owners were unfamiliar with the components of their septic systems. Those who reported having cesspools generally had a septic system also. Holding tanks are used by only 5% of the lake residents. Only 2% reported having no wastewater disposal systems.

Septic System Problems (see Question 21). Septic system problems were defined as backups, ponding on the surface, and/or odors. Overall, 25% of the lake residents reported having had at least one problem with their septic systems. This value ranged from

39% along the South Shore to 14% in Chitwood Addition. North Shore residents reported an 18% incidence of problems and Beanblossom Creek residents reported 20%. Part of the reason for the higher reported incidence of problems along the South Shore may be attributed to the low slope (0-2%) of much of the area (see Figure 4-52 and Table 4-14). The silt loam soil of the low terrace has a severe limitation for septic systems due to slow percolation. In contrast much of the land along the North Shore is steeply sloping (20-75%). The silt loam soils here also have a severe limitation for septic systems chiefly due to slope. However, malfunctions of the septic system would be less evident to the home owners in the form of backups, ponding and/or odors because of the steep slope.

There does not appear to be a clear-cut correlation between the age of the wastewater disposal system and the occurrence of problems (see Figure 4-53). The highest incidence (44%) of problems was found in the 0-5 year old category. This was followed by 19% in the more than 15 year old group, 18% in the 11-15 year old group and 11% in the 6-10 year old group.

More than twice the number of septic systems which have been pumped have had problems compared with those systems which have not been pumped (see Figure 4-53). Septic tank pumping is a frequent problem response rather than a problem cause, despite the fact that failure to periodically pump out a septic system can cause it to fail.

As expected, a higher frequency of septic system problems was found in year-round residences than in seasonal homes (see Figure 4-53). 30% of the year-round residences had encountered problems as compared to 19% of the seasonal residences. The distinction here is the continual wastewater loading which year-round septic systems receive.

In summary, the variables which show the strongest correlation with the occurrence of septic system problems appear to be lakeshore location and length of occupancy (i.e. year-round vs. seasonal).

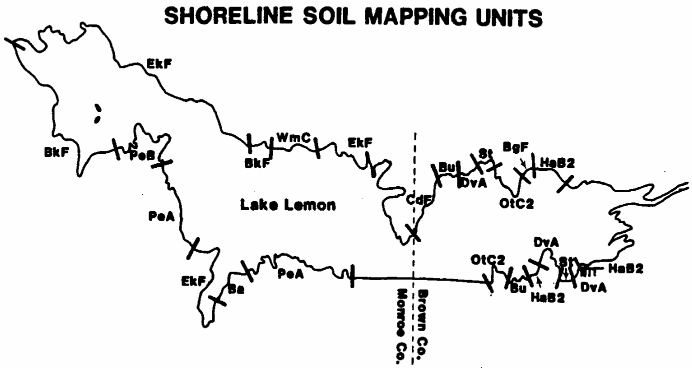


Figure 4-52. The location of soil mapping units along Lake Lemon's shoreline.

TABLE 4-14. SOILS AND RESIDENTIAL LAND USE ALONG THE MONROE COUNTY SHORELINE OF LAKE LEMON

Map Symbol	Name[1]	Physiography[1]	Shoreline Milage[2]	Number of Houses[3]	Hazard for septic tank absorption fields
BkF	Berks-Weikert Complex, 29-75% slopes	steep hillsides	2.57	30	severe/depth/slope
EkF	Elkinsville silt loam, 20-40% slopes	lower slopes	5.13	57	severe/slope
WmC	Wellston-Gilpin silt loams, 6-20% slopes	ridge tops	0.55	4	moderate/depth slope/percs
PeA	Pekin silt loam, 0-2% slopes	low terraces	1.08	24	severe/wet/percs
PeB	Pekin silt loam, 2-6% slopes	low terraces	0.75	5	severe/wet/percs
Ba	Bartle silt loam	terraces	0.75	0	severe/wet/percs
Hd	Haymond silt loam	well drained bottoms	0.25	3	severe/floods
TOTAL			10.48	108	

[1]Source: Thomas et al., 1981
[2]Determined by wheel gauge on soil survey maps
[3]Counted from aerial photographs

INCIDENCE OF SEPTIC SYSTEM PROBLEMS

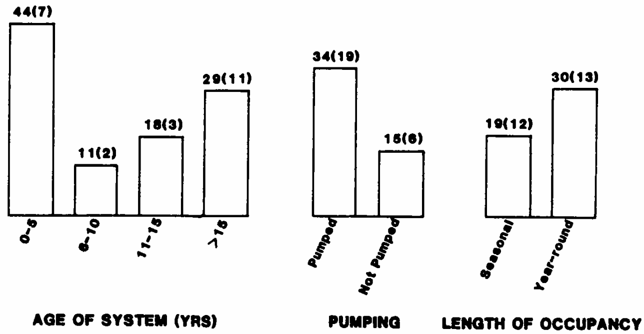


Figure 4-53. Incidence of septic system problems as a function of three criteria. Category percentage and number of respondents are given for each column.

Conclusions

Questionnaires were distributed to Lake Lemon shoreline residents and nearby Beanblossom Creek residents during June 11-July 3, 1982. The following observations were drawn from the questionnaire replies.

1. Over one-half of the residents live at the lake seasonally, especially during spring and summer.
2. The residents rank the four most important lake quality problems as: submerged aquatic plants, lake filling, shoreline erosion and algal blooms.
3. The majority of the older residents (more than five years at the lake) believe the lake's condition has gotten worse in the period they have lived on the lake. About 80% of those who lived on the lake less than five years felt the lake's condition had stayed the same or improved in that period of time.
4. The favorite uses of Lake Lemon are: observing the lake's beauty, motor boating, fishing, and swimming.
5. The residents feel the lake uses of swimming and power boating have been most negatively affected by a deterioration in the lake's quality.

6. Only one-quarter of the residents use fertilizer on their lawns.

7. Over 80% of the residents receive their drinking water from a rural water association.

8. Most of the housing development in the area occurred prior to 1971.

9. Almost all of the lakeshore residents have stabilized their shorelines.

10. The majority of residents use septic tank wastewater disposal systems.

11. Year-round residents and those living along the South Shore were most likely to report problems with their septic systems.

4.6.3 Septic Leachate Survey of Lake Lemon's Shoreline

Introduction

A septic leachate detection survey of most of Lake Lemon's developed shoreline was completed during the second week of July, 1982. The main purpose of the survey was to ascertain if a large number of septic tank plumes were entering Lake Lemon and thereby responsible, in part, for the excesssive weed growth problem. The location of possible septic leachate plumes was facilitated by using a commercially available instrument, called a Septic Leachate Detector (SLD), which was designed specifically for this purpose. The significance of tentatively identified plumes was ascertained by collecting (grab) water samples from such plumes and completing selected water analyses including fecal coliform bacteria, soluble reactive phosphorus and nitrate-nitrogen.

Equipment

The Septic Leachate Detector is an instrument that is capable of detecting effluents of septic systems by responding to a combined change in conductivity and fluorescence. The SLD used at Lake Lemon was an ENDECO (Environmental Devices Corporation, Marion, Massachusetts) Type 2100 Septic Leachate Detector System (Figure 4-55). The instrument and its theory are described by excerpts from the manufacturer's operation manual as reported in (Peters 1982):

"The ENDECO Type 2100 Septic Leachate Detector System is a portable field instrument that monitors two parameters, fluorescence (organic channel) and conductivity (inorganic channel). The system is based on a stable relationship between fluorescence and conductivity in typical leachate outfalls. Readings for each channel appear visually on panel meters while the information is recorded on a self-contained strip chart recorder. Recording modes are selectable between individual channel outputs or a combined output. The combined output is the arithmetic result of an analog computer circuit that sums the two channels and compares the resultant signal against the background to which the instrument was calibrated. The resultant output is expressed as a percentage of the background. Also, the combined recorded output is automatically adjusted for slow background changes. The system can be operated from a small boat enabling an operator to continuously scan an expansive shoreline at walking pace and, through real time feedback, effectively limit the need for discrete grab samples to areas showing high probability of effluent leaching. Expensive laboratory time for detailed nutrient analysis is greatly reduced while survey accuracy is increased substantially.

...The unit [is] powered by a standard 12-volt automotive battery. The plug-in, flow-through conductivity cell is in series with the fluorometer. The probe/wand houses a marine-type centrifugal pump. Discrete samples may be drawn directly from the instrument discharge for subsequent laboratory analysis...

Wastewater effluent contains a mixture of near UV fluorescent organics derived from whiteners, surfactants and natural degradation products that are persistent under the combined conditions of low oxygen and darkness...

Aged effluent percolating through sandy loam soil under anaerobic conditions reaches a stable ratio between the organic content and chlorides which are highly mobile anions. The stable ratio (cojoint signal) between fluorescence and conductivity allows ready detection of leachate plumes by their conservative tracers as an early warning of potential nutrient break-throughs or public health problems.

The Septic Leachate Detector System consists of the subsurface probe, the water intake system, the logic analyzer control unit, panel meters and the strip chart recorder....

The probe/wand is submerged along the shoreline. Background water plus groundwater seeping through the shore bottom is drawn into the subsurface intake of the probe and is lifted upwards to the analyzer unit by a battery operated, submersible pump.

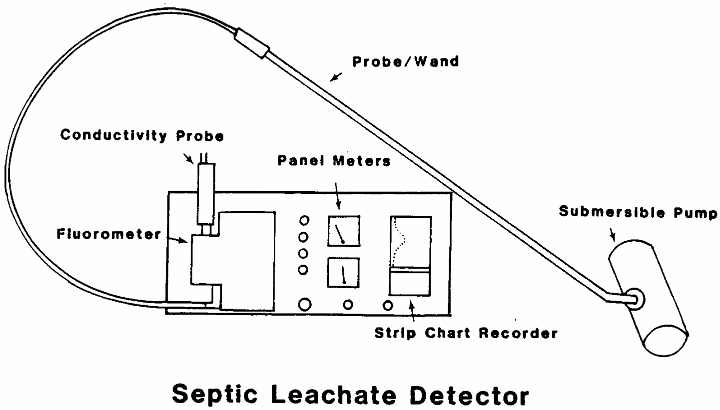


Figure 4-54. Schematic diagram of the ENDECO Type 2100 Septic Leachate Detector System.

Upon entering the analyzer unit the solution first passes through the fluorometer's optical chamber where a continuous measurement is made of the solution's narrow band response to UV excitation. The solution then flows through a conductivity measurement cell. An electrode-type conductivity/thermistor probe continuously determines the solution's conductivity. The solution exits the conductivity cell directly to the discharge where discrete samples may be collected if indicated by the response of the leachate detector. Both parameters are continuously displayed on separate panel meters. Zero controls are provided for both parameters (organic and inorganic) to enable "dialing out" the background characteristics to provide maximum sensitivity, as well as enhancing the response caused by a suspected abnormality. Span controls are also provided to control the sensitivity of each parameter separately during instrument calibration. This is helpful in determining relative concentrations of leachate outfalls.

The signals generated and displayed on the panel meters are also sent to an arithmetic/comparator analog computer circuit designed to detect changes in the ratio of organics and inorganics typical of septic leachate. The output of this circuitry is recorded continuously on a strip chart and is the key indicator of a suspected leachate outfall. However, isolated increases in either parameter may be cause for concern and should be sampled for analysis for other potential forms of nutrient pollution."

The SLD used on Lake Lemon was on loan from the U.S. Environmental Protection Agency, Region V, Chicago. The survey team consisted of a boat operator, a person to guide the instrument's probe and a person to operate the SLD. A fourth person was added on days when water samples were taken.

Methods

The septic leachate survey was performed in two phases during the period of July 9 - 15, 1982. The first three days were spent scanning the lakeshore and Beanblossom Creek for effluent plumes as indicated by elevated fluorescence and conductivity readings. The last three days involved rescanning areas with previous plumes and collecting water samples. The survey was conducted during early morning hours, usually between 5:00 - 10:00 AM, while the air was calm and lake mixing at a minimum.

In choosing the shoreline lengths to be scanned, emphasis was placed upon those along Lake Lemon and Beanblossom Creek with housing development. The actual scanning was done on a reach-by-reach basis. Each reach was a fairly continuous stretch of shoreline houses.

Before beginning to scan a reach, the instrument was calibrated against an assumed unpolluted central position of the lake. With the motor in trolling speed, the boat was then guided as close to shore as possible to allow the instrument probe to be extended to the shoreline. In this way an entire reach was scanned and the locations of plumes were noted.

During the second part of the survey, those reaches with previous plumes were rescanned. Water samples were collected when the instrument was calibrated and also in the vicinity of the peak of the plumes. Samples for SRP and fecal coliform bacteria analysis were placed in glass bottles. Samples for nitrate-nitrogen analysis were collected in polyethylene bottles. Soluble reactive phosphorus samples were filtered immediately in the field prior to storage. All of the samples were kept chilled in ice chests for transport to the city's lab. All analyses were conducted by the City of Bloomington's laboratory using procedures described previously.

Figure 4-55 presents a base map of Lake Lemon showing the shoreline reaches scanned and where water quality samples were collected. Figure 4-56 illustrates individual shoreline reaches scanned and the locations where water samples were collected.

Results and Discussion

Table 4-15 presents the results of water quality analyses completed by the City of Bloomington. As shown, most of the phosphorus analyses were below the limit of detection (<0.01 mg/l). Similarly, most of the samples showed low nitrate- nitrogen levels, with concentrations usually <0.01 mg/l. Exceptions are water samples collected along Beanblossom Creek above Lake Lemon when nitrate-nitrogen levels were in the 0.16 - 0.23 mg/l range.

Fecal coliform bacteria levels were generally below the Indiana bathing standard of 400 colonies/100 ml, however; a few sites had levels too numerous to count (TNC). Samples with high levels of fecal coliform bacteria were collected at the Chitwood Addition and along Beanblossom Creek.

A reach-by-reach description of the results from the water quality tests is given below. The reader should refer to Table 4-15 for the results of the water quality analyses and Figure 4-56 for the location of sampling sites.

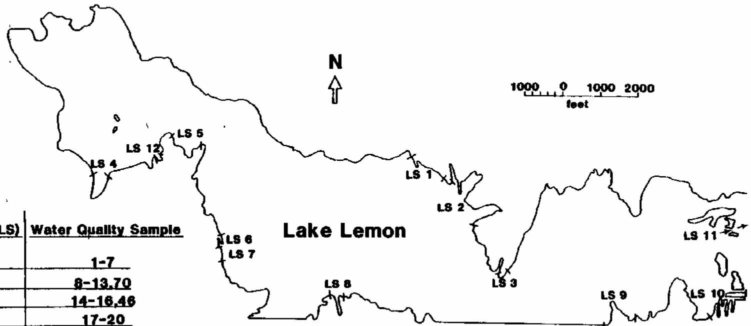
LS 1 - North Shore, Center Lobe

Water samples one - seven were collected in this reach and all show low nutrient concentrations of 0.01 mg/l or less of NO_3-N and SRP. Fecal coliform bacteria counts were also low except for sample #4 which had a count of 960/100 ml, compared with 10/100 ml for the reference samples.

LS 2 - North Shore Howell's Marina Area

In this reach all of the water samples had low nutrient concentrations of 0.01 mg/l of NO_3-N and SRP. Samples #9 and #70, which are from the same sampling site, had fecal coliform bacteria counts of 780/100 ml and TMC respectively, these are considerably higher than the reference sample's count of 0/100 ml.

SEPTIC LEACHATE SURVEY - WATER SAMPLING LOCATIONS

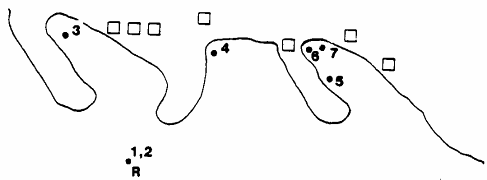


Lake Section (LS)	Water Quality Sample
1	1-7
2	8-13,70
3	14-16,46
4	17-20
5	21-23
6	24-26
7	27-29
8	30-35
9	39-45
10	47-61
11	62-69
12	71

Figure 4-55. Septic leachate survey lake sections and water quality sample locations.

LS 1 - North Shore, Center Lobe

(Samples 1-7)



LS 2 - North Shore/Center Lobe, Howell's Marina Area

(Samples 8-13,70)

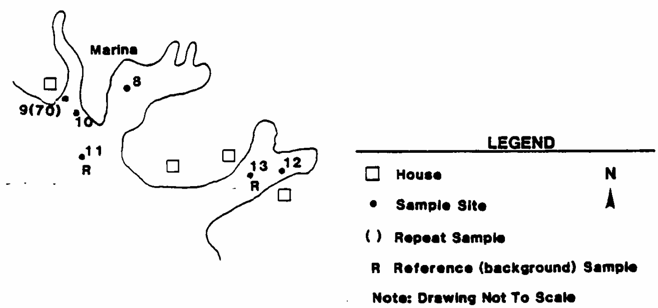
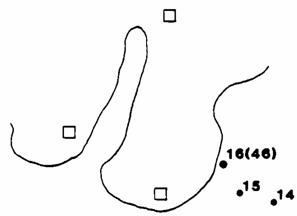


Figure 4-56 a. SLD survey water quality sampling locations for Lake Sections 1 and 2.

LS 3 - North Shore , Reed Point

(Samples 14-16,46)



LS 4 - South Shore, Cove West of Riddle Point

(Samples 17-20)

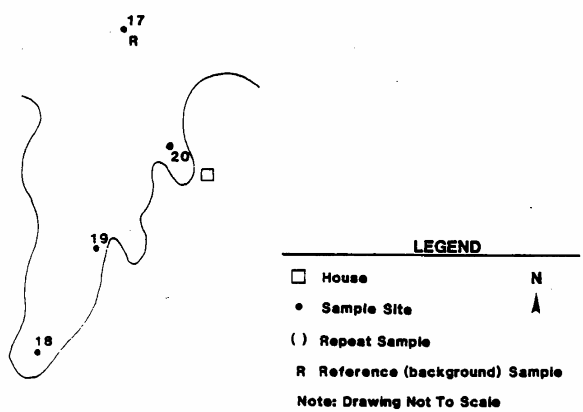
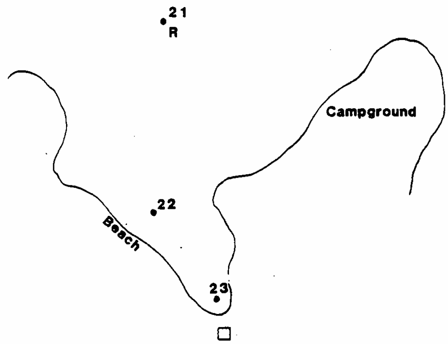


Figure 4-56 b. SLD survey water quality sampling locations for Lake Sections 3 and 4.

LS 5 - South Shore, Riddle Point Area
(Samples 21-23)



LS 6 - South Shore, Boat Garage Area
(Samples 24-26)

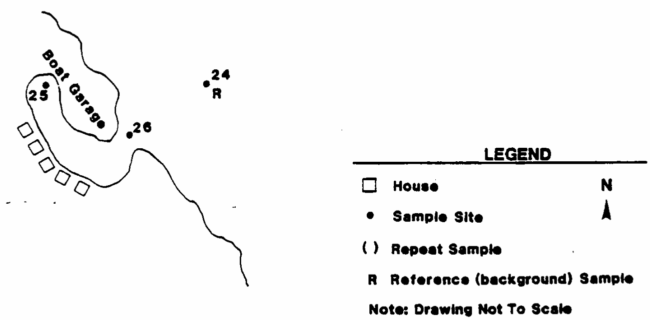
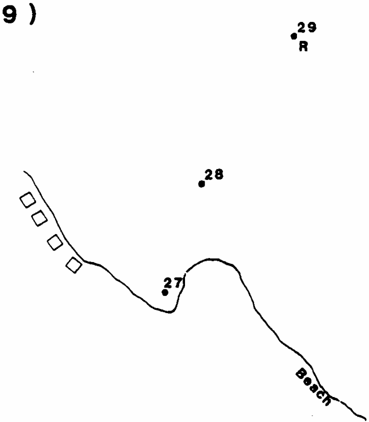


Figure 4-56 c. SLD survey water quality sampling locations for Lake Sections 5 and 6.

LS 7 - South Shore, I.U. Sailing Club Area

(Samples 27-29)



LS 8 - South Shore, Bloomington Yacht Club Area

(Samples 30-35)

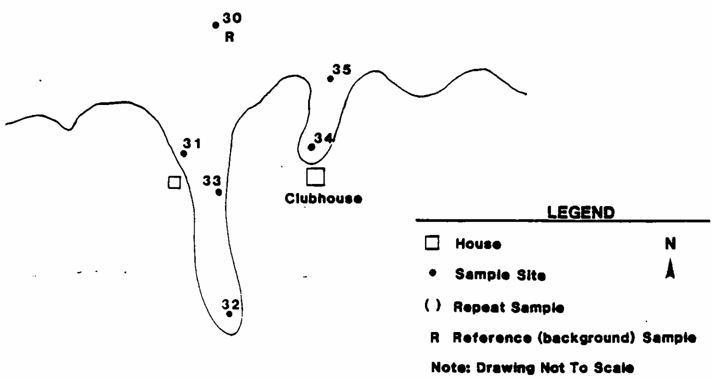
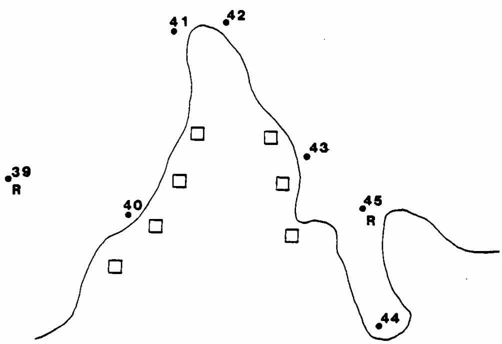


Figure 4-56 d. SLD survey water quality sampling locations for Lake Sections 7 and 8.

LS 9 - South Shore, Easternmost Cove

(Samples 39-45)



LS 10 - South Shore, Chitwood Addition

(Samples 47-61)

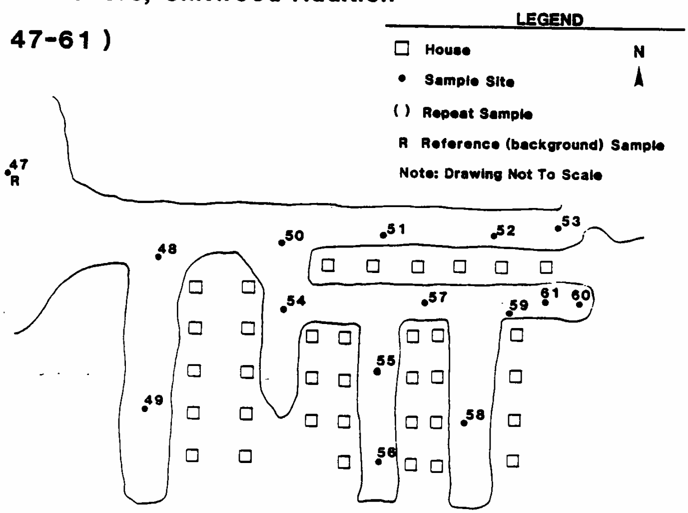
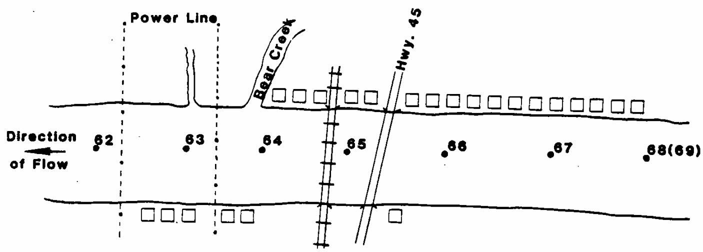


Figure 4-56 e. SLD survey water quality sampling locations for Lake Sections 9 and 10.

LS 11 - Bean Blossom Creek Channel Area

(Samples 62-69)



LS 12 - South Shore, Lake Manager's Cove Area

(Sample 71)

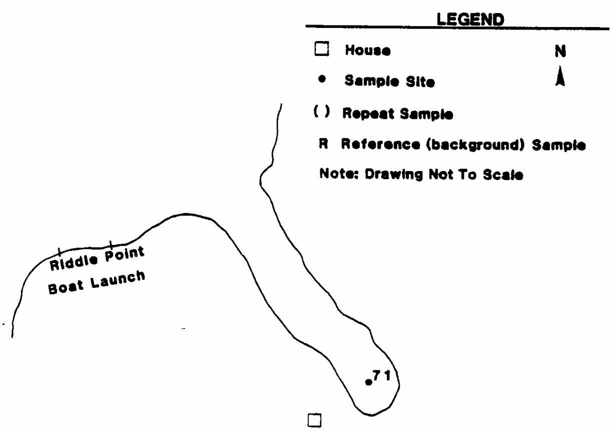


Figure 4-56 f. SLD survey water quality sampling locations for Lake Sections 11 and 12.

TABLE 4-15. WATER QUALITY DATA COLLECTED IN SUPPORT OF SEPTIC LEACHATE SCANS ON JULY 13-15, 1982

Date	Sample No.	Fecal Coliform (No./100 ml)	Nutrient Conc. (mg/l) NO_3-N	SRP
7/13/82	1	10	.01	.01
	2	10	.01	.01
	3	40	.01	.01
	4	960	.01	.01
	5	20	.01	.01
	6	30	.01	.01
	7	60	.01	.01
	8	20	.01	.01
	9	780	.01	.01
	10	20	.01	.01
	11	0	.01	.01
	12	50	.01	.01
	13	30	.01	.01
	14	0	.01	.01
	15	0	.01	.01
	16	0	.01	.01
	17	0	.01	.01
	18	110	.01	.01
	19	40	.01	.01
	20	0	.01	.01
7/14/82	21	72	.01	.01
	22	6	.01	.01
	23	8	.01	.01
	24	26	.01	.01
	25	16	.01	.01
	26	8	.01	.01
	27	22	.01	.01
	28	48	.01	.01
	29	214	.01	.01
	30	12	.01	.01
	31	TNC*	.01	.01
	32	420	.01	.01
	33	14	.01	.01
	34	16	.01	.01
	35	4	.01	.01
	36	0	.01	.01
	37	16	.01	.01
	38	14	.01	.01
	39	130	.01	.01
	40	0	.01	.01
	41	6	.01	.01
	42	504	.01	.01
	43	324	.01	.01
	44	TNC	.01	.01
	45	32	.01	.01
	46	6	.01	.01

*Too numerous to count

TABLE 4-15. (continued) WATER QUALITY DATA COLLECTED IN SUPPORT OF SEPTIC LEACHATE SCANS ON JULY 13-15, 1982

Date	Sample No.	Fecal Coliform (No./100 ml)	Nutrient Conc. (mg/l) NO_3-N	SRP
7/15/82	47	TNC	.01	.01
	48	TNC	.01	.01
	49	50	.01	.01
	50	120	.01	.01
	51	122	.01	.01
	52	160	.01	.01
	53	20	.01	.01
	54	180	.01	.01
	55	TNC	.01	.01
	56	TNC	.01	.01
	57	TNC	.02	.01
	58	TNC	.03	.01
	59	TNC	.01	.01
	60	TNC	.04	.01
	61	TNC	.03	.01
	62	TNC	.23	.01
	63	TNC	.22	.01
	64	0	.17	.01
	65	TNC	.19	.01
	66	TNC	.16	.01
	67	TNC	.19	.01
	68	TNC	.21	.01
	69	TNC	.21	.01
	70	TNC	.02	.01
	71	TNC	.01	.01

The remaining samples in this scan had fecal coliform bacteria levels of 50 colonies /100 ml or less.

LS 3 - North Shore, Reed Point

The results from water samples showed low nutrient concentrations of less than 0.01 mg/l of NO_3-N and SRP and low fecal coliform bacteria counts of six colonies/100 ml or less.

LS 4 - South Shore, First Cove West of Riddle Point

All of the water samples in this reach had nutrient concentrations of less than 0.01 mg/l of NO_3-N and SRP and low fecal coliform bacteria counts. Sample 18 had a slightly higher fecal coliform bacteria count of 110 colonies/100 ml than the reference sample's count of 0 colonies/100 ml. The other samples had fecal coliform bacteria counts of 40 colonies/100 ml or less.

LS 5 - South Shore, Riddle Point Area

Samples in this reach all contained low nutrient levels of 0.01 mg/l or less of NO_3-N and SRP and low fecal coliform bacteria counts of 72 colonies/100 ml or less.

LS 6 - South Shore, Boat Garage Area

All of the samples in this area showed low nutrient levels of less than 0.01 mg/l of NO_3-N and SRP and low fecal coliform bacteria counts of 26 colonies/100 ml or less.

LS 7 - South Shore, IU Sailing Club Area

In this reach the samples all had low nutrient concentrations of less than 0.01 mg/l of NO_3-N and SRP. The reference sample (#29) had a slightly higher fecal coliform bacteria count of 214 colonies/100 ml than either of the other two samples.

LS 8 - South Shore, Bloomington Yacht Club Area

Nutrient concentrations of less than 0.01 mg/l of NO_3-N and SRP were present in all samples. The fecal coliform bacteria counts of samples 31 (TMC) and 32 (420 colonies/100 ml) were much higher than the reference sample's count of 12 colonies/100 ml. The remaining samples had low fecal coliform bacteria counts of 16 colonies/100 or less.

LS 9 - South Shore, Most Eastern Cove

Each of these samples had a low nutrient concentration of less than 0.01 mg/l NO_3-N and SRP. Sample 42, 43 and 44 showed elevated fecal coliform bacteria counts of 504 colonies/100 ml, 324 colonies/100 ml and TNC/100 ml, respectively. Fecal coliform bacteria levels in the other samples ranged from 0-130 colonies/100 ml.

LS 10 - Chitwood Addition

All fifteen of the water samples for this lakeshore scan, except samples 49 and 53, showed fecal coliform bacteria counts exceeding 100 colonies/100 ml. Samples 48, 55 - 61, and the reference sample (47) had fecal coliform levels of TNC. In Sample 57, 58, 60, and 61 the NO_3-N concentrations ranged up to 0.04 mg/l, slightly higher than the reference sample's level of 0.01 mg/l. The SRP levels were less than 0.01 mg/l in all samples collected in this area.

LS 11 - Beanblossom Creek

Except for Sample 64, all of these samples (including the reference sample) showed fecal coliform bacteria counts of TNC. The NO_3-N values in this reach ranged from 0.16 mg/l to 0.21 mg/l, significantly higher than all the other samples. All of the samples had SRP concentrations of less than 0.01 mg/l.

LS 12 - South Shore, Lake Manager Cove

The only sample taken in this reach showed a high fecal coliform bacteria count of TNC and low nutrient concentrations of less than 0.01 mg/l NO_3-N and SRP.

Conclusions

A septic leachate survey was conducted along the Lake Lemon and Beanblossom Creek shoreline during July, 1982. A total of 71 water samples were taken for nutrient and fecal coliform bacteria analyses. The following observations were drawn from the sampling results and are valid only for the time period sampled:

(1) There does not appear to be any shoreline areas having nitrate and SRP concentrations above the background levels in the center of the lake.

(2) Very little NO_3-N and SRP seem to be reaching the shoreline of Lake Lemon from septic effluents or plumes.

(3) There are scattered lake locations, including most of the Chitwood Addition and lower section of Beanblossom Creek where the fecal coliform bacteria levels exceed Indiana's Water Quality Standard for full-body contact recreation (for discrete samples) of 400 colonies/100 ml.

(4) Fecal coliform bacteria data for some lake reaches were inconclusive. In such cases, the reference samples contained higher levels of fecal coliform bacteria than the shoreline samples.

CHAPTER 5: WATER BUDGET

5.1 OVERVIEW

The water budget for Lake Lemon was derived using the following mass balance equation:

$$\Delta V = (P-E) + R + G - S_o$$

where:

ΔV = change in storage in lake

$(P-E)$ = net precipitation (precipitation - evaporation) to the lake surface

R = (basin) surface runoff

G = groundwater inflow

S_o = surface outflow

The water budget for the 1982 water year is presented in Table 5-1.

The 1982 Water Year can be considered a typical year from a hydrologic viewpoint. Figure 4-5 shows that, in all but one month, the 1982 mean monthly flows at the USGS gage in Beanblossom, Indiana fall within one standard deviation of the 20-year average for this site; the odd month falls within two standard deviations. Component derivation is discussed in the following section.

5.2 DETERMINATION OF HYDROLOGIC COMPONENTS

Net precipitation (P-E) was calculated using data from the National Oceanic and Atmospheric Administration's monthly summaries for the period of record. Total monthly precipitation was taken from the weather station at Bloomington, Indiana. Pan evaporation data were taken from the station at Dubois S. Indiana Forage Farm, which was the nearest station. In months when evaporation was not recorded every day, the monthly total was divided by the number of recorded days and then multiplied by the number of days in that

TABLE 5-1

Water Balance for Lake Lemon - 1982 Water Year

(All values are expressed as m^3)

Month/yr	Net Precipitation (P-E)	Surface Runoff (R)	Change Lake Volume (V)	Lake Outflow (S_o)	Groundwater Inflow (G)
10-81	1.46×10^3	2.65×10^5	2.59×10^5	5.25×10^5	neg*
11-81	1.02×10^4	3.53×10^5	2.90×10^5	6.53×10^5	neg
12-81	5.52×10^5	3.30×10^6	7.20×10^5	4.65×10^6	neg
01-82	9.04×10^5	2.14×10^7	-0-	2.32×10^7	neg
02-82	3.58×10^5	1.24×10^7	-2.94×10^5	1.42×10^7	2.15×10^6
03-82	6.69×10^5	1.55×10^7	-0-	1.76×10^7	2.38×10^6
04-82	-1.85×10^5	8.26×10^6	-4.40×10^5	1.02×10^7	2.30×10^6
05-82	-4.54×10^4	2.77×10^6	-1.44×10^5	3.97×10^6	2.38×10^6
06-82	1.13×10^5	5.07×10^6	7.36×10^4	6.71×10^6	2.30×10^6
07-82	2.63×10^4	1.21×10^6	-2.20×10^5	1.99×10^6	neg
08-82	1.62×10^5	4.24×10^5	3.64×10^5	8.10×10^5	neg
09-82	-4.68×10^4	5.35×10^5	-6.58×10^5	9.58×10^5	neg
TOTAL	2.25×10^6	7.15×10^7	-4.94×10^4	8.55×10^7	1.15×10^7

*negligible

month, yielding an adjusted monthly evaporation value. No distinction has been made between adjusted and total evaporation values. A pan coefficient of 0.7 (Chow 1964) was used to convert observed evaporation values to estimated values for Lake Lemon. Also, it was assumed that the surface area of the lake does not change with precipitation or evaporation. (P-E) values were consequently multiplied by 5.83 x 10^6 m^2 (1440 acres) to obtain total monthly net precipitation in m^3.

Total surface runoff (R) was calculated using streamflow measurements made throughout the Lake Lemon watershed during the 1982 water year and corresponding data from the USGS gaging station at Beanblossom, Indiana. Streamflow measurements were made monthly or biweekly (May through August) at predetermined sampling sites according to the methods described in Section 4.2. The gage height at the Beanblossom gage was recorded whenever a sampling trip was made, and the corresponding discharge was interpolated from USGS's current discharge rating curve (no. 34) for this site. Streamflow correlation curves were then prepared for each sampling site. These plots consisted of a relationship between instantaneous streamflow at the sampling site versus that at the Beanblossom gage (see Figures 4-2 through 4-4 for examples). Mean monthly streamflows at the Beanblossom gage were retrieved via telephone from the USGS in Indianapolis, and applied to the correlation curves to obtain estimates of the mean monthly stream flows at each sampling site.

Mean monthly streamflow for the ungaged area of the Lake Lemon watershed (watershed area not measured by sample sites) was estimated as follows:

1. Mean monthly flows at sample sites E, F, and G were expressed into terms of runoff (cfs) per square mile of drainage area (cfs/mi^2);

2. These calculated unit runoff values were then averaged to yield an estimated average flow per square mile;

3. The total drainage area represented by sites E, F, and G was subtracted from the Lake Lemon watershed area yielding the total ungaged area; and

4. The ungaged area was multiplied by the average unit runoff and then converted to m^3.

Mean monthly flows at E, F, G, and ungaged area were then added to obtain the total monthly surface runoff entering Lake Lemon.

Change in storage (ΔV) was determined via direct observation of changes in lake elevation at two sites on the lake during the last half of the 1982 water year. Previous to that, the change in storage was synthesized from the following information: (a) direct measurements of outflow; (b) gage readings at the outflow works; and (c) outflow estimates based on streamflow records at the Beanblossom Creek gage.

Surface outflow (S_o) was determined in two ways. First, it was calculated using the mass balance equation, assuming a net groundwater flow of zero. Second, it was regularly measured below the outlet (Site A), and later these flow rates were correlated to flow at the Beanblossom gage.

Total groundwater inflow (G) was calculated as a residual since other authors (Hartke and Hill 1974) have stated that groundwater flow in the Lake Lemon basin is negligible. It was assumed that groundwater inflow was responsible for the discrepancy between calculated and measured outflow at Site A. The total difference was allocated to those months of the year when the monthly difference was greatest and/or when evidence of groundwater inflow was observed.

5.3 DISCUSSION

The data in Table 5-1 indicate the major components of the Lake Lemon water budget. They are surface runoff, which accounts for 84% of the total water input, and surface outflow, which accounts for virtually all outflow from the lake. Most of the water movement through Lake Lemon occurred from January through April, when 80.5% of total surface runoff and 76.3% of surface outflow occurred.

To further understand the hydrology of Lake Lemon, an effort has been made to calculate the hydraulic residence time. The hydraulic residence time, Tw, is defined as the ratio of the water (lake) volume to the annual water inflow volume, and represents the average time necessary to exchange the total volume of water within a lake.

The following equation (Rast and Lee 1978) was used to calculate residence time:

$$T_w = \frac{V}{Q}$$

where: V = lake volume (m^3)
Q = annual water inflow rate (m^3/yr)

The 1982 Lake Lemon volume was calculated using the following information (Hartke and Hill 1974):

Original lake volume (1953) = $1.77 \times 10^7\ m^3$
Sedimentation rate = 0.17%/yr
Estimated lake volume (1982)= $1.69 \times 10^7 m^3$

When applied to the water budget for Lake Lemon, the following residence time was obtained:

$$T_w = \frac{V}{Q} = \frac{1.69 \times 10^7 m^3}{8.52 \times 10^7 m^3/yr} = 0.20 \text{ years}$$

The inverse of T_w is the rate of flow, or flushing rate (P). Flushing rate, calculated via the equation $\rho = \frac{Q}{V}$, describes the number of times per year that the lake volume is replaced. For Lake Lemon, ρ = 5.0 volumes per year. Most of this flow occurred from January through April, when the highest nutrient loadings also occurred. This relatively high flushing rate has important consequences with regard to the nutrient budget, and will be discussed in Section 6.0.

The groundwater component of the water budget is a theoretical component, calculated as described in Section 5.2. We have reason to believe that there is, in fact, positive groundwater flow, based on the observation that one section of the lake's south end was the last to freeze and the first to thaw. This freezing pattern could not be correlated to any other externalities, such as surface runoff, wind patterns, or path of sunlight.

CHAPTER 6: NUTRIENT BUDGET

6.1 OVERVIEW

The reasons for constructing a nutrient budget for the Lake Lemon watershed are twofold: (a) to determine the relative trophic state of the lake and (b) to determine whether the lake is acting as a phosphorus source or sink. This information can then be used in planning a lake management strategy.

It is generally agreed that the three most important factors affecting the growth of algae and macrophytes are phosphorus, nitrogen, and carbon, the essential nutrients (Simpson and Reckhow 1979). We have focused on phosphorus in the nutrient budget since it is considered the most manageable of these nutrients (see Chapter 7.0 for a complete discussion).

The phosphorus loading to Lake Lemon was calculated by two methods - an empirical phosphorus loading model and measured values.

6.2 PHOSPHORUS LOADING MODEL

Phosphorus loading to Lake Lemon was estimated by using phosphorus export coefficients found in the literature (Simpson and Reckhow 1979). An export coefficient represents the expected annual amount of phosphorus transported, per unit of source (e.g., per acre of farmland), to a surface water body. Because this model is a simplification, high, low, and mid-range estimates of phosphorus loadings were considered (Table 6-1). The selection of an export coefficient from a particular category is dependent on conditions present in the watershed of study. For Lake Lemon, the mean of the midrange value was used, unless measured values suggested otherwise. Because of the results of the septic leachate survey (see Section 4.6.3), septic systems were not included as phosphorus sources.

Predicted phosphorus load from precipitation was calculated by multiplying the lake's surface area ($5.83 \times 10^6 m^2$) by the

TABLE 6-1. PHOSPHORUS EXPORT COEFFICIENTS USED IN "PREDICTED" PHOSPHORUS CALCULATIONS

	Phosphorus Export Coefficient, $kg/10^6m^2/yr$			
Range	Agriculture	Forest	Precipitation	Urban
HIGH	200	80	60	200
MID	20-50	10-50	20-50	70-120
LOW	10	2	15	50

Source: Simpson and Reckhow (1979)

phosphorus export coefficient (35 $kg/10^6m^2/yr$). Predicted phosphorus load from surface runoff was based on a detailed land use analysis of the Lake Lemon watershed. Land uses not represented by export coefficients were placed in appropriate classifications. For example, campgrounds were considered forest land, and wetlands and pasture were considered agricultural land. Water bodies (ponds and Lake Lemon) were excluded from the total watershed area for the purpose of this analysis. Results are summarized in Table 6-2.

6.3 MEASURED PHOSPHORUS LOAD

Regularly measured streamflows and total phosphorus concentrations were used in the following equation to calculate phosphorus loading to Lake Lemon:

$$L = Q \quad C$$

where: L = phosphorus load
Q = total inflow
C = phosphorus concentration

Measured phosphorus load from surface runoff was determined as follows:

TABLE 6-2. PREDICTED PHOSPHORUS LOADING TO LAKE LEMON BASED ON LAND USE DATA

Land Use	Land Area Area ($10^6 m^2$)	Coefficient ($kg/10^6 m^2/yr$)	Phosphorus Load (kg/yr)
Agriculture	35.6	35	1,246
Forest	134.0	30	4,020
Urban	3.3	95	315
		TOTAL	5,581

1. Graphs of instantaneous phosphorus load versus streamflow were prepared for Sites E, F, and G, (Figure 4-1) and regression lines plotted. (Loads were calculated and multiplied by a ratio of total subdrainage area to subdrainage area represented by the site).

2. Mean monthly flows at each site (see Section 5.2) were applied to the above graphs to determine mean monthly phosphorus loads.

3. Phosphorus loading from the ungaged area was estimated by extrapolation, a method similar to that used in Section 5.2 for estimating ungaged streamflow.

4. The phosphorus load for each month of the 1982 Water Year was determined by adding individual loadings from E + F + G + ungaged areas.

The measured phosphorus load exiting the lake via surface outflow was based on streamflow measurements and phosphorus concentrations at Site A below the outlet. Streamflow measurements were made downstrem from the outlet structure, while phosphorus samples were taken either directly at the sluiceway or the spillway, depending upon where water was leaving the lake on the sampling dates. Phosphorus samples were not taken at the stream gaging site because of a possible erroneous phosphorus load due to suspended sediment inflows downstream from the outlet works. When phosphorus concentration data were not reported for Site A, values from Site B were used (the lake site nearest the outlet). The concentration of phosphorus at the lake bottom was used if flow occurred through the sluiceway, and at the lake surface if flow occurred over the spillway. If there was more than one sampling trip per month, phosphorus concentrations were averaged, and the mean concentration was used.

Mean monthly flow at Site A was determined from streamflow correlation curves (see Section 4.2). This flow was used to determine monthly phosphorus loads.

The phosphorus load due to direct precipitation on Lake Lemon was estimated from literature values. Pecor et al. (1973) reported a mean annual total phosphorus concentration of 27 ug/l in precipitation over Houghton Lake, Michigan and Kluesener (1972) reported a mean annual total phosphorus concentration of 32 ug/l in precipitation over Lake Wingra, Wisconsin. The average of these two values (30 ug/l) was used to characterize mean annual total phosphorus concentrations of precipitation at Lake Lemon. This estimated concentration was multiplied by the total precipitation for the 1982 water year recorded at the Bloomington, Indiana weather station (114 cm) and by the lake's surface area according to the following equation:

$$L = QP \ [P] \ A$$

where: L = mass phosphorus loading from precipitation (kg/yr)

QP = annual precipitation (114 cm/yr)

$[P]$ = mean phosphorus concentration (30 ug/l)

A = lake surface area ($5.83 \times 10^6 m^2$)

6.4 DISCUSSION

Table 6-3 shows that approximately 80% of the total phosphorus load into and out of Lake Lemon occurs from January through April.

TABLE 6-3. MEASURED TOTAL PHOSPHORUS LOAD INTO AND OUT OF LAKE LEMON

	Phosphorus Loading (kg)	
Month/Year	Surface Runoff	Surface Outflow
October 1981	11.7	37.3
November 1981	15.8	39.8
December 1981	162	236
January 1982	1,151	944
February 1982	639	866
March 1982	818	1,073
April 1982	430	516
May 1982	134	141
June 1982	254	225
July 1982	56.9	80.7
August 1982	19.8	37.0
September 1982	24.1	38.9
TOTAL	3,716	4,235

This seasonal high loading of phosphorus to the lake is due to the relatively high flushing rate of Lake Lemon (discussed in Section 5.3). Note also that during the period May - December the outflow of total phosphorus from Lake Lemon usually equals or exceeds the surface inflow loading rate. This suggests that Lake Lemon is not a sink of phosphorus.

The overall phosphorus budget is presented in Table 6-4. The predicted budget using the phosphorus loading model is incomplete because no literature citation was found for estimating the phosphorus load leaving a lake. However, the budget based on data collected throughout the 1982 Water Year (measured data) indicates a

Table 6-4. SUMMARY OF PREDICTED AND MEASURED PHOSPHORUS LOADINGS FOR LAKE LEMON

	Phosphorus Loading, kg/yr			
	Precipitation (P)	Surface Runoff (R)	Surface Outflow (S_0)	Excess (E)
PREDICTED[1]	204	5,581	-	-
MEASURED[2]	199	3,716	4,235	-320

[1]using phosphorus loading model (Simpson and Reckhow 1979)

[2]1982 Water Year, this study

net reduction of phosphorus of 320 kg per year from Lake Lemon. In this situation, the lake itself is acting as a nutrient source, with the excess phosphorus most likely being recycled from the sediments.

The discrepancy between the predicted and the measured budget component led us to take a second look at the export coefficients used for the predicted value for surface runoff. When the lowest values of the mid range are used (Table 6-1), the predicted value for the surface runoff loading of phosphorus is 2283 kg/yr. This is considerably lower than the 5,581 kg/yr value given in Table 6-4 which was calculated from the mean phosphorus export coefficients in the mid range. The annual phosphorus loading due to surface runoff estimated by our measured values falls between these ranges.

Since the excess phosphorus calculated via the nutrient budget (using measured components) comprises less than 10% of the total inputs to Lake Lemon, we hesitate to conclude that there is a net export of phosphorus from Lake Lemon. This excess output of phosphorus may, in fact, be negated by phosphorus coming into Lake Lemon via groundwater flow. It seems safe to say, however, that Lake Lemon is not likely a major phosphorus sink.

CHAPTER 7: RESTORATION TECHNIQUES REVIEW

7.1 INTRODUCTION

Lake restoration techniques can be divided into two categories: in-lake techniques and watershed management practices. In-lake techniques generally treat the symptoms of a particular problem, while watershed management practices treat problem sources. Generally, watershed management practices produce long-term solutions and in-lake techniques produce more immediate, but temporary, results. There are situations where the source of the problem comes from within the lake, such as with internal nutrient recycling. Such a problem was treated successfully at Medical Lake, near Spokane, Washington with alum precipitation. Unfortunately, watershed management practices are much more expensive and difficult to carry out than in-lake techniques. An ideal lake restoration scheme may include both types of treatment. Congress, in creating Clean Lakes Program (PL 92-500, Sections 104 & 314) stressed this type of management approach, and EPA has used it as a criterion for approving Clean Lakes grant proposals.

The need for restoration is usually indicated by one or more of the following symptoms:

1. Excessive mass of primary producers.
2. Increased populations of aquatic plants.
3. Rapid accumulation of sediments.

Of these, the first two can often be controlled by curbing nutrient input to the lake and/or removing nutrients from the lake system. Unless other environmental conditions such as light availability or temperature are limiting, primary producers and macrophytes will respond directly to the level of nutrients to which they are exposed.

Either phosphorus or nitrogen can be the limiting nutrient in the growth of aquatic organisms. Limnologists focus on the relationship between phosphorus and plant communities in lake ecosystems for the following reasons:

1. Phosphorus is scarce relative to other necessary nutrients; the N:P ratio necessary for sustained plant growth is 7:1.

2. Many studies indicate that cultural activities are the major source of phosphorus loading to a lake and are therefore relatively easy to control.

3. Removal of phosphorus is technologically easier and more cost-effective than removal of nitrogen.

All of the restoration techniques discussed in the following sections have been tested to varying degrees. The success of any one technique depends on the extent to which a lake has been characterized (physically, chemically, and biologically) before choosing the appropriate alternative, and the precision with which that alternative is applied to the particular situation. It helps, too, to set out a specific restoration goal, and by so doing, identifying situations that must be avoided. As will be seen below, a restoration technique aimed at solving one problem may create another problem as its side effect.

A number of restoration summaries have been published, often as sections of larger reports. The <u>Survey of Lake Rehabilitation Techniques and Experiences</u> (Dunst et al. 1974) is a comprehensive treatment of restoration techniques including case studies. More up-to-date reports stemming from EPA's Clean Lakes Program give a better idea of the relative success of the technique described. Many of these reports are cited in the following sections.

7.2 WATERSHED MANAGEMENT PRACTICES

The EPA has established five objectives to be accomplished by the Clean Lakes Program, one of which emphasizes watershed management. This goal is attainable through watershed best management practices (BMPs) which are "designed to control or treat pollutants at their sources prior to discharge into surface water bodies and reduce the hydraulic loading in combined sewer systems" (Parrish 1982). Included under the heading of watershed BMPs are the following approaches:

1. Agricultural controls, such as:
   a. tillage and planting practices
   b. waste storage ponds
   c. buffer strips

2. Urban controls, such as:
   a. comprehensive land use planning
   b. runoff storage
   c. street cleaning
   d. improved waste treatment

7.2.1 Agricultural Controls

Agricultural controls are particularly crucial in Indiana, where about 87% of the total land area is agricultural. The Lake Lemon watershed includes an atypical 19% of agricultural land. Normal agricultural practices have the potential to seriously degrade surface water quality. Land clearing, tillage, irrigation systems, confined animal feedlots, and fertilization are among the practices which can increase both sedimentation and nutrient loading to water bodies, thus accelerating the eutrophication process. It has been reported that agricultural runoff is the greatest single contribution of nitrogen and phosphorus to water (Parrish 1982). Much of this nutrient loading is associated with soil erosion and the adsorption of nitrogen and phosphorus to soil particles. Other substances transported similarly can include pesticides, toxic chemicals, metals, organic and inorganic matter, and pathogens. Sedimentation, not only decreases lake volume and increases macrophyte substrate, but also contributes organic and inorganic substances to the lake ecosystem.

The Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS) of the U.S. Department of Agriculture, have provided both technical and financial assistance for erosion control to farmers and water pollution control agencies. A number of Soil Water Conservation Practices (SWCPs) have been developed to combat agricultural pollution; for a thorough treatment of these see Parrish (1982). SWCPs specific for erosion and runoff control are mentioned briefly in the paragraphs that follow.

One of the most effective techniques for controlling soil loss is no-till farming. Part of this strategy involves leaving the vegetative cover to decompose on the soil surface, which prevents surface sealing, increases infiltration, and decreases the volume and velocity of runoff (Parrish 1982). As a side effect, loss of soluble plant nutrients is increased. As a whole, however, no-till significantly reduces soil loss and nutrient runoff over conventional tillage practices. Similarly, "conservation tillage refers to any system that protects the surface with crop residues (Parrish 1982)".

Another group of SWCPs are based on impeding the natural direction of surface flow with perpendicular barriers. Included are contouring, ridge plants, contour listing, and strip cropping. These practices, too, act to control surface runoff and erosion.

Sod-based rotations decrease runoff by increasing soil porosity. Fields planted in cover crops show a reduction in runoff as compared with fallow fields. By increasing flow path length and decreasing slope, terraces are effective in erosion control. Flow velocity is also decreased by buffer strips, which reduce water velocities and permit suspended sediments to settle out.

The increase of livestock production under confined conditions has resulted in special problems in pollution and waste management. Animal wastes are a major source of nutrients, pathogens, and BOD to lakes and streams. To meet these relatively new demands, the SCS provides technical assistance in this area. The SCS has developed a number of practices that utilize the following strategies:

1. Construction of waste storage facilities.
2. Channelling contaminated runoff into temporary storage ponds.
3. Reduction of solids loadings to storage ponds.
4. Diversion of clean water runoff to avoid contact with livestock and manure storage areas.

Specific practices are discussed in detail by Fogg (1981).

7.2.2 Urban Controls

The need for urban watershed controls has been demonstrated by a variety of studies, including Colston's (1974) report entitled

"Characterization and Treatment of Urban Land Runoff." This report found that urban land runoff controlled downstream water quality 10% of the time. Runoff from a 1.67 square mile urban watershed contained about one-half of the organic load and 2 to 50 times the concentrations of heavy metals and solids when compared with typical sanitary wastes in the area (Parrish 1982). Figures like these clearly indicate that urban land runoff can be a significant source of water pollution. In order to accurately evaluate this problem, the U.S. EPA's National Urban Runoff Program (NURP) is conducting comprehensive studies of urban areas nationwide.

Specific strategies for controlling urban runoff pollution will not be discussed here, as they do not apply to the Lake Lemon watershed. It is important to note, however, that urban controls are often an integral part of watershed BMPs. For more information on this subject, see Parrish (1982) and Dunst et al. (1974).

7.3 IN-LAKE RESTORATION TECHNIQUES

In-lake restoration techniques for the most part treat the consequences of overfertilization in lakes rather than the actual sources of pollution. These techniques include precipitation of phosphorus, dredging, aeration, dilution/flushing, sediment sealing, lake level drawdown, and macrophyte controls. Again, most of these focus on limiting phosphorus concentrations in lakes. It will be reemphasized here that in-lake restoration techniques can only be effective in lakes where significant watershed nutrient sources have been mitigated.

7.3.1 <u>Phosphorus Precipitation/Inactivation</u>

Precipitation and inactivation of phosphorus is designed to remove phosphorus from the water column and to prevent release of phosphorus from sediments. This nutrient control strategy is aimed at minimizing planktonic algal growth. The use of phosphorus precipitation for macrophyte control has been unsuccessful due to increased light penetration after floc formation. A floc is an agglomeration of small particles formed when aluminum salts are added to the lake. This floc (e.g. $Al(OH)_3(S)$ acts in two ways: (a) it adsorbs phosphorus from the water column as it settles, and

(b) it seals the bottom sediments if a thick enough layer has been deposited. Phosphorus can also precipitates out as an aluminum salt (e.g. $AlPO_4$ (S)). Cooke and Kennedy (1981) have suggested seven criteria for successful lake treatment:

1. Dose.
2. Choice of dry or liquid chemical.
3. Depth of application.
4. Application procedure.
5. Season.
6. Side effects.
7. Lake types best suited for the technique.

Most phosphorus precipitation treatments have employed liquid aluminum sulfate (alum) or sodium aluminate. The dosages are determined by the standard jar test, keeping in mind that aluminum solubility is lowest in the pH range 6.0 to 8.0. Cooke and Kennedy (1981) offer a detailed dose determination method. Chemicals added for phosphorus control are applied either to the lake surface or to the hypolimnion, depending upon whether water column or sediment phosphorus control is most necessary.

The application procedure of aluminum salts to lake water has changed little since the first treatment in Horseshoe Lake, Wisconsin (Peterson et al. 1973). At Horseshoe Lake, alum slurry was pumped from a barge through a manifold pipe that trailed behind the vessel just below, and perpendicular to, the surface. A frontal distribution system would take better advantage of the barge for mixing and distribution of chemical.

The season of application is critical for phosphorus removal, since different forms of phosphorus predominate in the water column on a seasonal basis. Phosphorus removal is most effective in early spring when most phosphorus is in an inorganic form which can be removed almost entirely by the floc.

Aluminum toxicity does not appear to be a problem at treatment concentrations in well-buffered lakes. As mentioned previously, phosphorus precipitation promotes water clarity, which could allow for increased macrophyte growth.

Phosphorus inactivation has been effective for as long as six years. In shallow, wind-swept lakes or in such parts of lakes, however, the floc may break up and lose its capabilities as a sealant.

7.3.2 Dredging

Sediment removal by dredging removes phosphorus enriched sediments from lake bottoms, thereby reducing the likelihood of phosphorus release from the sediments. This technique has added benefits of lake deepening for recreational purposes and for limiting the growth area for rooted macrophytes. Because this technique is capital-intensive, it can only be justified in small lakes or in lakes where the sediment-bound phosphorus is limited to a small, identifiable area. Dredging is not effective in lakes where additional sediment loading cannot be controlled. In deep lakes, the cost of dredging can be prohibitive. Sediment removal might also be justified in a seepage lake, where watershed controls are not applicable.

A potentially troublesome consequence of dredging is the resuspension of sediments during the dredging operation and the possible release of toxic substances bound loosely to sediments. Because of this, sediment cores must be analyzed prior to dredging to determine sediment composition. Such an analysis would also provide a profile of phosphorus concentrations with depth in the sediments. If phosphorus concentrations do not decline with depth, dredging for phosphorus control would not be effective since phosphorus could continue to be released from the sediments.

Perhaps the most economically and logistically prohibitive part of a dredging operation is disposal of the sediments removed. Sediment disposal must be carefully investigated before the decision to dredge can be made.

7.3.3 Aeration

Hypolimnetic aeration is a technique used to remedy oxygen depletion in the bottom waters of a stratified lake without disturbing the existing thermal conditions. There are two basic aeration strategies: (a) air or oxygen is introduced directly to the hypolimnion, and (b) the hypolimnetic water is pumped to the lake surface or to an onshore splash basin where it is aerated before being returned to the lake bottom. Crucial to the success of this process is the size of the aerator. Lorenzen and Fast (1977) present methods for estimating the size of aerator required according to the following parameters:

1. Hypolimnetic volume.
2. Hypolimnetic oxygen depletion rates.
3. Oxygen input capacity and yearly aeration period.

The effects of hypolimnetic aeration on the improvement of water quality are both direct and indirect. Aeration has direct effects on taste and odor, the lake's cold water fishery and winter fish kills, and indirect effects on phytoplankton. Hypolimnetic aeration can remove iron and hydrogen sulfide, both of which contribute to taste and odor problems. It can also prevent phosphorus release from the sediments, but the nutrients moved upward via aeration could negate the immediate beneficial effect. In stratified eutrophic lakes, aeration provides a source of oxygen for otherwise anoxic bottom water, creating a suitable environment for cold water fishes, a refuge for zooplankton, and preventing winter fish kills. It is the expansion of zooplankton habitat, if anything, that aids in control of algae. Because the zooplankton can better escape their predators, they become more effective in controlling their prey, the algae. Hypolimnetic aeration has no known adverse effects on water quality.

A similar technique, artificial circulation, produces some different results. The strategy is the same -- to provide oxygen to anoxic bottom waters in stratified lakes. Circulation techniques range from high-energy mixing devices to low-energy aerators, and include mechanical pumps, rising air bubbles, and jets of water. Aeration is accomplished via atmospheric exchange at the lake surface. Since lakes are most often artificially mixed after stratification occurs, the procedure is also known as artificial destratification. One advantage to mixing before stratification is that bottom waters will be low in nutrients.

In addition to improving taste and odor qualities and reducing incidents of winter fish kills, artificial circulation can decrease turbidity and algal blooms by distributing the algae throughout the water column. Circulation may destroy a lake's cold water fishery by introducing warmer epilimnetic waters into the hypolimnion.

7.3.4 Dilution/Flushing

The dilution/flushing technique is effective in controlling algal growth, as demonstrated in Green and Moses Lakes, in the state of Washington. These case histories can be found in Welch (1981). Water quality improvement is accomplished via two mechanisms: (a) limiting nutrient concentrations are lowered and (b) water exchange rates are increased. An additional benefit, algal cell washout, can control algal blooms if the water exchange rate approaches the algal growth rate.

The availability of low-nutrient dilution water is most crucial to this restoration technique. Dilution will occur as long as dilution water has a lower nutrient concentration than the lake water; effectiveness will increase as the difference between inflow and lake concentrations becomes greater. Ideally, long-term reduction of limiting nutrients is attained via a low-rate input of low-nutrient water. Existing high-nutrient inputs must also be diverted to complete this restoration scheme. If low-nutrient water is unavailable, a high-rate input of moderate to high-nutrient water may be effective in a short-term nutrient reduction because of algal cell washout.

Costs associated with dilution/flushing are highly variable depending on the proximity of dilution water and the availability of facilities to deliver it. According to Welch (1981), the cost of construction and first year maintenance and operation can be less than $100,000 if the lake is in an urban setting and domestic water is available.

7.3.5 Bottom Sealing

Covering bottom sediments is a relatively unresearched restoration technique in which a physical barrier prevents nutrient release and/or macrophyte growth. Clays and sheeting materials are two feasible cover materials (Table 7-1). The effectiveness of

TABLE 7-1. LAKE BOTTOM SEALING MATERIALS

Sheeting Material	Description	Cost (1979 $$)
Dupont Typar 3201/3202	finely porous black polypropylene	$ 2,600/ha[1]
black polyethylene	nonpermeable, buoyant	$12,558/ha
Hypalon	nonbuoyant synthetic rubber	$59,452/ha[1]
polyvinyl chloride (PVC)	nonbuoyant	$15,275/ha[1]
Permealiner	semipermeable black polypropylene, buoyant	$27,000/ha[1]
Aquascreen-62 aperture/cm^2	PVC-coated fiberglass screen	$140/7'x 100' roll[1]

1 material only

Source: Cooke (1980a)

clays as a sediment sealant is largely unknown and warrants further study. Sheeting materials available are summarized in Table 7-1.

Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials are generally more difficult to apply and must be weighted down. Sand or gravel anchors can act as substrate for new macrophyte growth. Materials must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners.

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in lakes with high siltation rates, since silt accumulated on the sheeting material provides an area for macrophyte growth.

7.3.6 Lake Level Drawdown

Lake level drawdown can be used as a macrophyte control technique or as an aid to other lake improvement techniques. Drawdown can be used to provide access to dams, docks, and shoreline stabilizing structures for repairs, to allow dredging with conventional earthmoving equipment, and to facilitate placement of sediment covers.

As a macrophyte control technique, drawdown is recommended in situations where prolonged (one month or more) dewatering of sediments is possible under conditions of severe heat or cold and where susceptible species are the major nuisances. Myriophyllum spicatum, control for example, apparently requires three weeks or longer of dewatering prior to a one-month freezing period (Cooke 1980). Cooke (1980b) classifies 63 macrophyte species as decreased, increased, or unchanged after drawdown. One must note the presence of resistant as well as susceptible species, since resistant species can experience a growth surge after a successful drawdown operation.

Macrophyte control is achieved by destroying seeds and vegetative reproductive structures (e.g., tubers, rhisomes) via exposure to drying or freezing conditions. To do so, complete dewatering and consolidation of sediments is necessary. Dewatering may not be possible in seepage lakes. This, in combination with the need for refilling after drawdown, points out the need for a water budget prior to choosing this technique in a lake restoration scheme.

There are a number of other benefits to lakes and reservoirs from drawdown. Game fishing often improves after a drawdown because it forces smaller fish out of the shallow areas and concentrates them with the predators (bass, walleye, pike). This decreases the probability of stunted fish and increases the winter growth of the larger game fish. Drawdown has also been used to consolidate loose, flocculent sediments that can be a source of turbidity in lakes. Dewatering compacts the sediments and they remain compacted after reflooding (see Born et al. 1973 and Fox et al. 1977).

A possible negative effect of lake drawdown is an increase in algal densities. This may occur in some lakes where the drawdown and exposure of sediments, and the subsequent aeration and oxidation, allows for the release of nutrients in the sediments upon reflooding. Benthic (bottom-dwelling) organisms in the exposed shallow areas may suffer, resulting in lower densities upon reflooding. In some cases, macrophyte species resistant to drawdown invaded the exposed lake bottom. Finally, drawdown must be timed to allow for sufficient refilling by water from the lake or reservoir's drainage basin.

A final consideration in implementation of lake level drawdown is season -- winter or summer are usually chosen because they are most severe. According to Cooke (1980b), "it is not clear whether drawdown and exposure of lake sediments to dry, hot conditions is more effective than exposure to dry, freezing conditions." One factor to consider is which season is most rigorous. Advantages of winter drawdown include less interference with recreation, ease of spring versus autumn refill, and no invasion of terrestrial plants. Sediment dewatering is easier in summer.

In Murphy Flowage, a 73 ha (180 acre) reservoir in Wisconsin, a five foot drawdown from mid-October to March greatly reduced the presence of aquatic macrophytes the following growing season. <u>Myriophyllum</u> spp. was reduced from 8 ha to <1 ha coverage, <u>Nuphar</u> spp. was reduced from 17 ha to 5 ha, and <u>Potanogeton</u> spp. was reduced from 46 ha to 3 ha (Beard 1973).

Lake level drawdown is an attractive restoration technique due to its low cost and because introduction of chemicals and machinery is not necessary.

7.3.7 <u>Harvesting</u>

Although macrophyte harvesting is not a long-term restoration method, it can manage the growth of aquatic macrophytes and give the lake user immediate access to activities that had been affected by excessive macrophyte growth; these include swimming, boating, and water-skiing. Harvesting can contribute to long-term restoration if the amount of nutrients removed in the cut vegetation exceeds the lake's net nutrient income, a virtual impossibility in eutrophic lakes.

Aquatic plants are either cut or cut and removed. The latter method is more costly and has the added problem of disposal of cut vegetation. On the other hand, vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen; there is also the danger that many harvested plants can re-root or reproduce vegetatively from the cut pieces if left in the water.

Algal blooms are known to occur sometimes after harvesting; few other adverse environmental impacts have been identified.

Mechanical harvesting costs vary according to capital cost and capacity of the harvester, amortization rate, amount of time required to unload harvested material, size of lake, and other factors. Depending upon the specific situation, harvesting costs can range up to $1600 per hectare (Prodan 1983; Adams 1983).

7.3.8 Biological Control

Biological control of algae and macrophytes via grazing of introduced organisms is a recent experimental approach to controlling excessive vegetation. Aquatic scientists are proceeding cautiously with research since introduction of exotic species can cause more problems than it solves. Advances have been made in the southern U.S. with insects and plant pathogens, largely in the control of alligatorweed and water hyacinths. The introduction of grass carp (Genus Ctenopharyngodon) has been successful as a macrophyte control technique in Red Haw Lake, Iowa, and in various Arkansas lakes. Because grass carp are notorious spreaders of fish disease in Europe, their general use in plant control has been restricted until further research can be done.

The use of grass carp in public or private waters of Indiana is illegal under current law. The Director of the Department of Natural Resources can issue special permits exempting scientific or educational studies of grass carp.

CHAPTER 8: FEASIBLE ALTERNATIVES

8.1 APPROACH

Any program to improve the water quality of Lake Lemon must address the major problems facing the lake. In summary, these are:

1. Heavy growth of aquatic macrophytes, specifically Eurasian water milfoil (Myriophyllum spicatum);

2. Sedimentation, particularly in the eastern end of the lake, and its related water column turbidity;

3. Shoreline erosion; and to a lesser extent

4. Periodic high concentrations of phosphorus and fecal coliform bacteria entering the lake from Beanblossom Creek.

There are two general approaches that can be used to address these problems:

1. Watershed management practices to control pollutants before they reach the lake; and

2. In-lake control and management to treat problems once they appear in the lake.

8.2 WATERSHED MANAGEMENT PRACTICES

The effect of Beanblossom Creek on Lake Lemon's water quality has been demonstrated by numerous figures in Chapter 4, the water budget in Chapter 5, and by the nutrient budget in Chapter 6. The water budget indicates that the water in Lake Lemon is replaced approximately five times a year, primarily by discharge from Beanblossom Creek. Therefore, by reducing the amounts of nutrients, fecal matter, and soil reaching Beanblossom Creek, the ultimate concentrations of these materials within Lake Lemon would also be reduced.

8.2.1 Land Use Considerations

Although there is a certain natural level of nutrients and soil reaching streams, by far the greatest contribution to stream pollutant loading is from human activities which disturb the soil. The magnitude of this pollutant loading has been related to the type of land use practices in a given stream's watershed. Many studies have concluded that nitrogen and phosphorus loadings to streams increase as the proportion of land in agricultural and urban land uses increases (Omernick et al. 1976; Humenik 1980). The amount of loading from agricultural lands can depend on agricultural cropping and management practices, annual weather conditions, and the presence of stream border buffer zones.

Agricultural practices that reduce erosion and runoff from the land include:

1. Reduced or no-till plowing.
2. Contour plowing.
3. Crop rotation.
4. Grassed waterways.
5. Unplowed buffer strips along streams.
6. Feedlot waste management systems.

The need for each of these management practices is evident at selected locations throughout Lake Lemon's drainage basin. Although agricultural land use in the drainage basin averages only 19% of total land use, most of it occurs on ridge tops or in the valleys adjacent to streams and other water courses.

Recommendations for agricultural management practices on specific lands is beyond the scope of this project. The U.S. Department of Agriculture, Soil Conservation Service (SCS) is the appropriate agency to carry out such assessments. In response to our request for assistance, a team of SCS officials inspected the Lake Lemon watershed on August 11, 1985 to evaluate its potential as a PL-566 multi-purpose watershed protection project. The PL-566 program is designed to protect, manage, improve and develop the water and related land resources of watersheds up to 250,000 acres in size. Federal technical, cost-sharing, and credit assistance is available for land treatment, nonstructural, and structural measures, including erosion and sediment control, flood prevention, recreation development, and others.

The results of the SCS inspection, included in Appendix H, were that while there is past evidence of erosion problems on cropland, current agricultural land use practices in the Lake Lemon watershed are good and erosion from these lands is not severe, averaging four to five tons per acre per year. Since cropland comprises only about 20% of Lake Lemon's watershed and occurs primarily on flat valley bottoms and adjacent gently sloping land, the SCS feels that the ongoing conservation programs administered by the Monroe and Brown County Soil and Water Conservation Districts are adequate to address any problems. Both of these programs encourage reduced tillage systems as erosion control measures. No additional program or funding for agricultural erosion control was recommended.

8.2.2 Streambank Erosion

Erosion of streambanks and channels by the natural cutting action of flowing water appears also to be a significant problem in a number of areas within Lake Lemon's drainage basin. The more critical areas include:

1. Beanblossom Creek from east of Helmsburg (Sampling Sites H and I) to the Highway 45 bridge at Trevlac.

2. Lower Plum Creek.

Structural streambank controls are used to either control streamflows or protect banks. Streamflow controls are designed to deflect current away from vulnerable banks, or to slow the current so that it will be less erosive.

Although many landowners believe stream meanders cause bank erosion and "straightened" streams reduce erosion, floodwaters in shortened and straight stream channels move even faster and cause more erosion, especially where streambanks are not stable. It is the speed of water runoff and streamflows that is the most important factor controlling erosion and the delivery of sediment to downstream areas (Roseboom 1985). Stream meanders and in-stream obstructions can help in reducing high stream velocities that cause streambank erosion.

Structural controls include (Soil Conservation Service 1982):

1. Deflectors constructed of posts, piling, fencing, rock, brush, or other materials that project into the stream to protect banks at curves and reaches subjected to impingement by high velocity currents.

2. Artificial obstructions, such as fences, to protect vegetation needed for streambank protection or to protect critical areas from damage from stock trails or vehicular traffic. Where needed, construct a permanent fence capable of excluding livestock from the streambanks. If livestock watering places are provided, the ramps leading to low water should be on a slope of 4:1 or flatter. The ramps should be surfaced with a suitable material to prevent erosion. Floodgates may be used at channel crossings, property, and other fence lines.

3. Riprap. This type of construction is particularly effective in the following situations: (1) sharp bends; (2) constrictions such as bridges where velocities are increased; (3) along the opposite bank where another stream junctions; and (4) on large streams. The bank should be sloped to a 1-1/2:1 side slope or flatter and the riprap properly underlaid with a filter blanket if necessary, to discourage wave penetration.

4. Gabions. Gabions are wire mesh baskets wired together and filled with rock in place. Banks should be sloped to a 1-1/2:1 side slope or flatter. If the bank material is a fine grained soil, use a 6-inch (15.2 cm) well-graded pit-run sand and gravel filter or filter cloth. A good example of the use of gabions is along Goose Creek at the Avoca State Fish Hatchery in Avoca.

Non-structural streambank erosion controls include:

1. Establishing and maintaining vegetative buffer strips along streambanks to intercept runoff before it flows down the streambank.

2. Keeping streambanks vegetated.

3. Banksloping to reduce steep streambank slopes. All banks to be seeded only and not riprapped should be sloped to a 2:1 side slope or flatter. All material excavated from sloped banks should be placed on the bank, leveled, and seeded to prevent erosion during high water. Excavated material should not be pushed into the stream or lake or form barriers which interfere with runoff entering natural drainage channels.

4. Removal of fallen trees, stumps, debris, minor ledge outcroppings, and sand and gravel bars that may cause local current turbulence and deflection.

5. Removal of trees and brush that adversely affect the growth of desirable bank vegetation.

Costs for streambank erosion controls vary widely. The lowest-cost stream stabilization is largely a stream maintenance method, which uses stream obstructions (logjams) as bank protection structures and flow deflectors. This method has been successfully applied in other states by private consulting firms. At sites where the lowest-cost method is not sufficient, dormant tree cuttings of willow and cottonwood can be placed in the eroding bank. The dormant cuttings will regrow root systems and branches to stabilize bank soil and deflect streamflow. The Soil Conservation Service in Arizona has successfully used this method in major rivers, including the Colorado River. It is more expensive than the first method because usually a large number of cuttings must be transported to the site (Roseboom 1985). The most expensive of the streambank erosion controls are the structural methods such as riprap.

8.2.3 Sediment Detention Basins

Wet detention basins are designed to allow permanent settling of sediments before they can enter a lake or stream. If well-designed and properly maintained, suspended solids removals of 70 to 90% are possible (Pitt 1985). Some sediment detention basin design features are shown in Figure 8-1. As a general rule, sediment detention basins should have an area roughly 0.5% of the watershed. If we apply this formula to Lake Lemon's 18,2000 ha watershed, 91 ha (225 acres) of detention basin area would be required.

8.3 IN-LAKE MANAGEMENT PRACTICES

Although there is some shoreline erosion along Lake Lemon that requires attention, the biggest problem in the lake identified by this study is the heavy macrophyte growth. Potential in-lake management practices are described in more detail below.

8.3.1 Shoreline Stabilization

Due, in part, to frequently changing lake levels, the shoreline surrounding Lake Lemon is unstable and eroding in many areas. The effects of recent shoreline erosion are evident by increased sediment depths near the effected areas (see Section 4.4). Approximately five km (three miles) of shoreline are in need of stabilization. Private

SEDIMENT DETENTION BASIN DESIGN CRITERIA

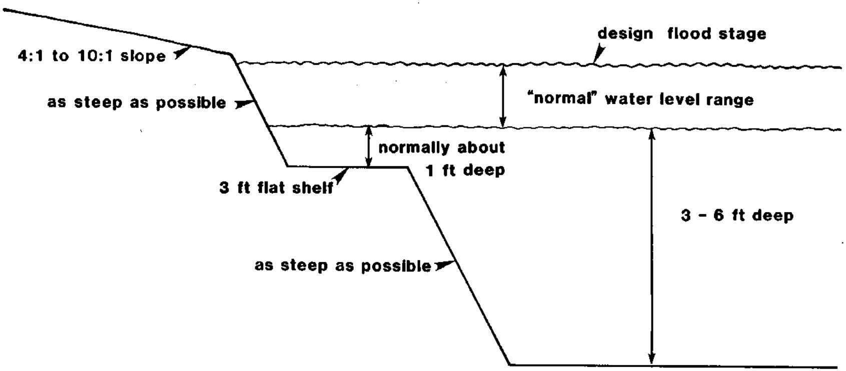


Figure 8-1. Some common sedimentation basin design criteria.

homeowners have used limestone quarry wastes, gravel, and wood and concrete sea walls to control shoreline erosion. The City of Bloomington has used rock rip-rap to stabilize the shoreline around Riddle Point. Other areas around Riddle Point Beach still require treatment. Some areas of the shoreline have been stabilized with vegetation. One particularly effective plant for doing this is a species of club moss (Lycopodium), which is stabilizing a five-foot high, vertical bank section along the southwestern shore of the lake.

Continued efforts to stabilize Lake Lemon's shoreline are recommended. Public education efforts can be used to bring attention to this problem and technical assistance, possibly from an appropriate City of Bloomington department, could be used to help shoreline owners determine available options for his or her property.

The following is a partial list of shoreline protection measures that may be used (Soil Conservation Service 1982):

1. Vegetation of the type that will grow across or along the waterline.

2. Bank Sloping. All banks to be stabilized should be sloped to a 2:1 slope or flatter. All material excavated from sloped banks should be placed on the bank, leveled and seeded to prevent erosion from runoff or wave run-up. Excavated materials should not be pushed into the lake.

3. Beaching Slope. Shore protection with beaching slopes utilize the movement of semi-fluid sands up the beach with breaking waves, and off the beach with receding waves to dissipate energy. For any given wave size, a beach will stabilize with a particular relationship between beach slope and the median grain size of the beach material. Criteria for design of a beaching slope are available from the SCS.

4. Riprap. This type revetment protects shoreline from wave action, ice action and slumping due to seepage. Riprap should be placed between 1.5 times the wave height below the still water surface and the runup plus 0.5 feet above the still water surface. Minimum stone size is 4" diameter and minimum thickness of the riprap should be 2.5 times the stone diameter.

5. Gabions. Gabions are rectangular containers constructed of heavy galvanized steel wire mesh. When anchored to the shoreline and filled with stone, gabions can stabilize highly eroded shorelines better than loose stone or riprap. Typical gabions are three feet wide and range from 6-12 feet long and 1-3 feet high (see Figure 8-2).

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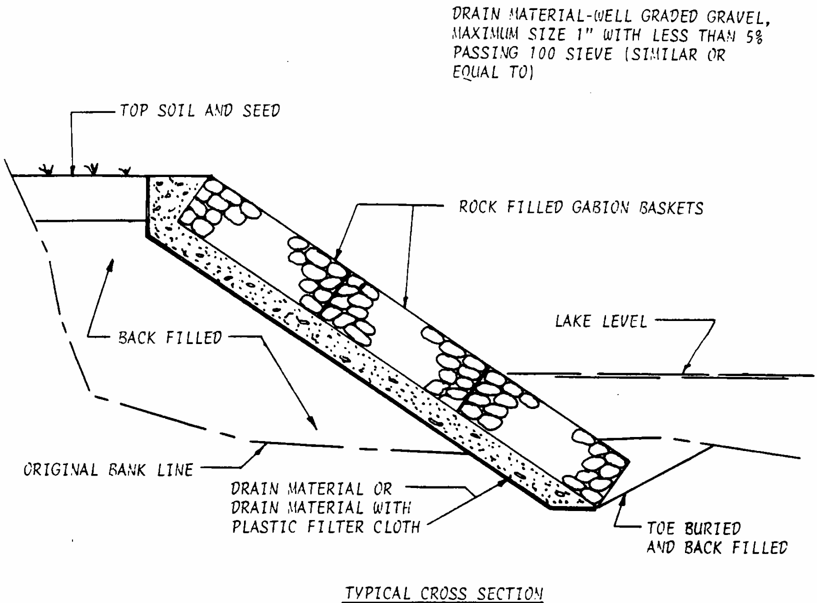
SOIL CONSERVATION SERVICE

DRAWING NO. WI-803 (2/82)



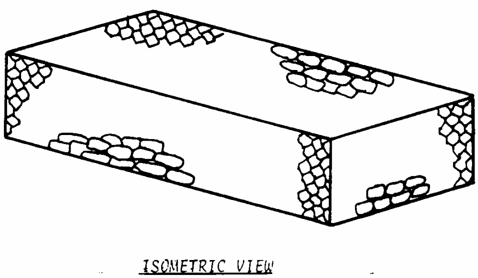


Figure 8-2. Typical drawing for lake shore protection using gabions.

6. Concrete. Concrete revetments for shore protection may be either (1) a sloping concrete apron which provides a nonerosive surface for waves to break against and run up on, or (2) a bulkhead type revetment used where steep banks prohibit the use of sloping forms of protection. The force of the waves acts on the bulkhead primarily in a horizontal direction. Footings for these structures should extend a minimum depth of 3 X wave height below still water elevation. The top of the revetment should extend a minimum of 1 foot (0.3 m) plus runup above still water elevation.

7. Piling. Piling is another type of revetment used where natural shorelines are too steep for sloping protection. Piling may be installed either vertically or with a slight batter. Minimum thicknesses for piling are:

Material	Minimum Thickness	
	in.	cm
Metal sheet	.109	.277
Wood plank	2.0	5.08
Wood pole	4.0	10.16

Wood planks and poles should be pressure treated. The land side of piling should be backfilled to absorb wave energy. For design of piling, the lake bottom may be considered stable at a depth of three X wave height below still water elevation. The top of the piling should be 1 foot (0.3 m) plus runup above still water elevation (Figures 8-3 and 8-4).

8. Groins. Groins are used to replace beach material removed by long shore currents. With the beach restored, waves break further from shore, reducing erosion of the bank. Groins are effective only where appreciable long shore currents exist. If the amount of sand carried by long shore currents (littoral drift) is small, the areas between groins may have to be artificially filled to establish a beach. Since the placement of groins tends to increase erosion on unprotected downdrift reaches of shoreline, location must be selective. Groins may be built of riprap, timber, steel, or gabions.

8.3.2 Macrophyte Control

While there are several species of rooted macrophytes present in Lake Lemon (see Section 4.7.2, Macrophytes), the only one requiring control at this time is *Myriophyllum spicatum* (Eurasian water milfoil). The other species are not abundant enough to be considered nuisances and, to the contrary, are beneficial by providing habitat for fish and other aquatic organisms. Table 8-1 reviews some positive attributes of shoreline vegetation (Nichols 1985).

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DRAWING NO. WI-801 (2/82)

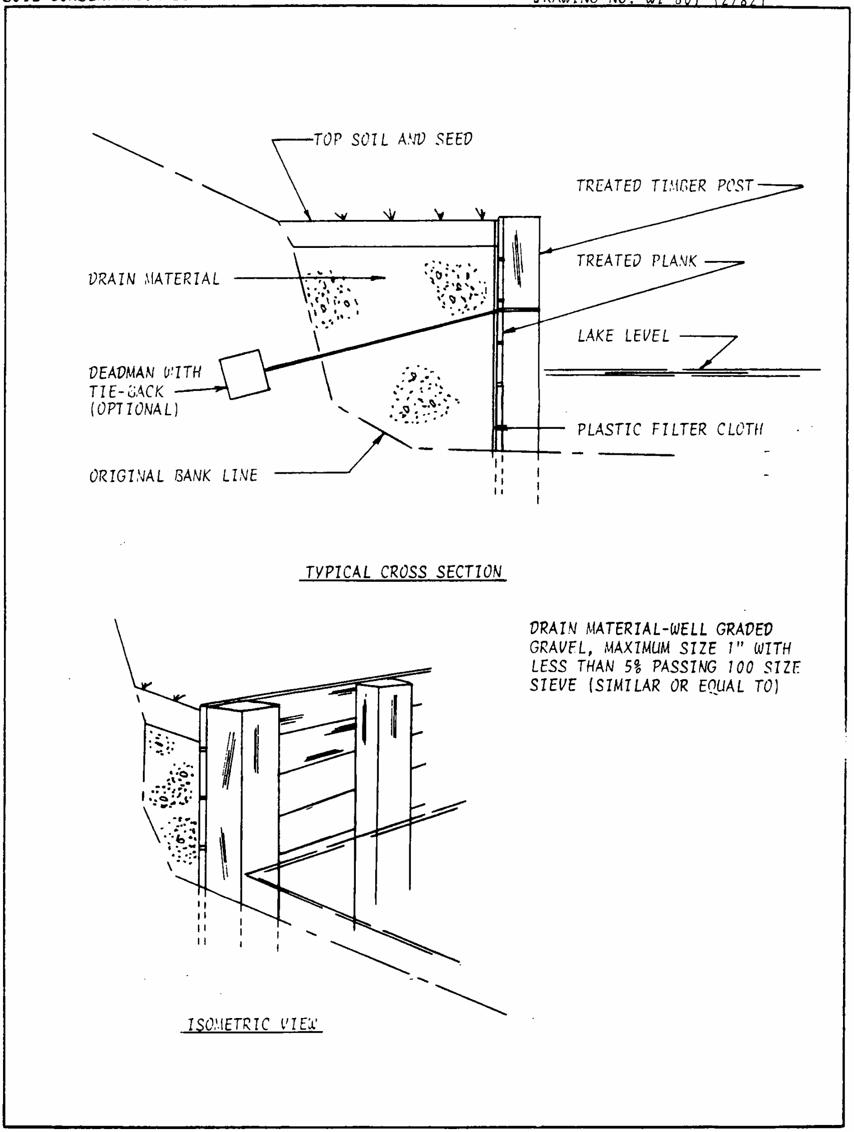

Figure 8-3. Typical drawing for lake shore protection using treated plank and post wall.

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SOIL CONSERVATION SERVICE

DRAWING NO. WI-802 (2/82)

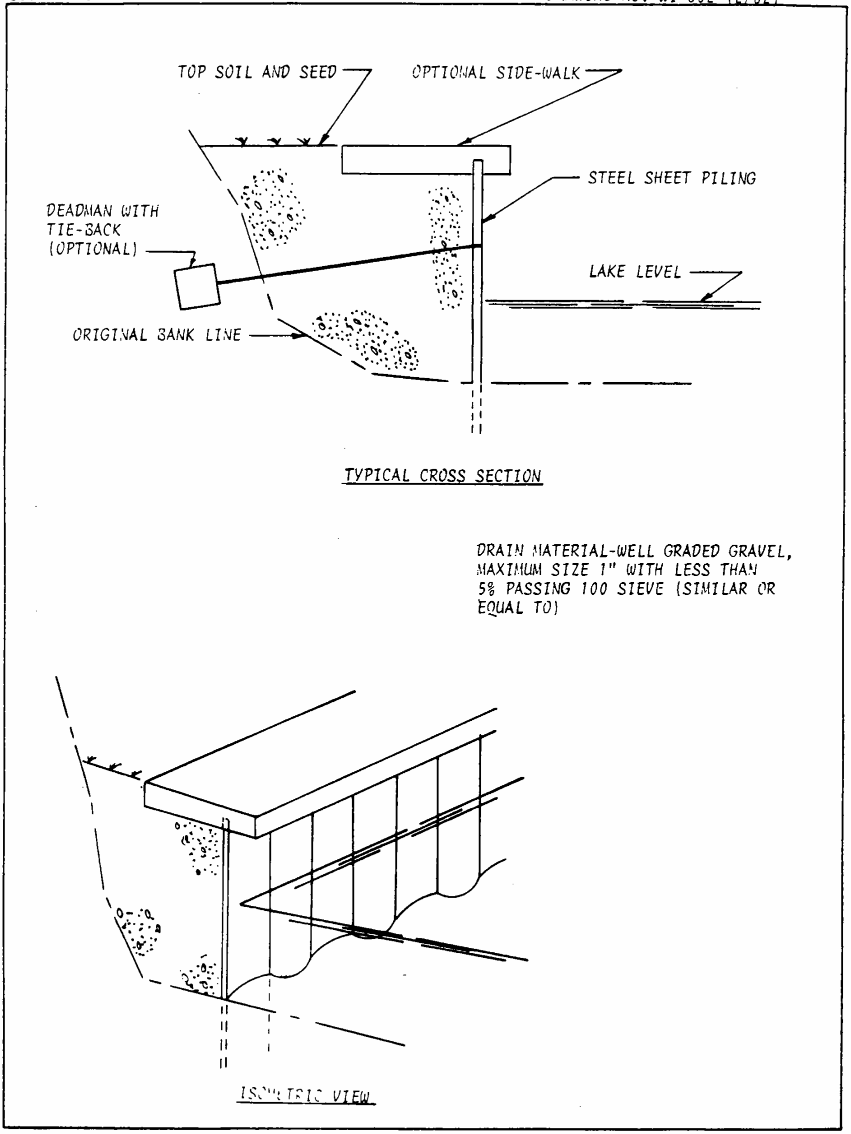

Figure 8-4. Typical drawing for lake shore protection using steel sheet piling wall.

TABLE 8-1. ATTRIBUTES OF THE SHORELINE VEGETATION BUFFER

POSITIVE ATTRIBUTES	RECOMMENDED PLANT TYPES
Shoreline Erosion Protection	Grasses, Emergents
Wave Dampening	Emergents
Screening	Emergents, Shrubs
Shade	Trees
Noise Buffer	Emergents, Shrubs
Aesthetics	Pretty Flower or Plant Form
Fish Cover	Submergents, Floating Leaved
Fish Spawning	Varies
Animal Cover	Emergents, Shrubs
Animal Nest Sites	Varies
Animal Food	Varies
Macroinvertebrate Habitat	Submergents

The level of *Myriophyllum* control deserves careful consideration because it provides important aquatic habitat. Fisherman, for example, find that the edges of *Myriophyllum* beds are good "fishing spots". Therefore, control must be balanced between the needs of the fisherman, boaters, homeowners, and the lake. Complete control of *Myriophyllum* at Lake Lemon is probably not technically nor economically feasible anyway. For the past several years, Lake Lemon problems have been managed by shoreline stabilization, winter drawdown, and chemical treatments applied to problem weed beds. While these management strategies are technically feasible and have had some success, there needs to be better coordination of management efforts built around a comprehensive, long-term plan. Suggestions for improving these efforts follow.

Lake Drawdown

Application to Lake Lemon. Fall and winter drawdown has been used as a management technique at Lake Lemon for the past several years. However, this technique has had limited success for the following reasons:

1. Drawdown was initiated too late in the fall.

2. The outlet structure has either not been opened enough or does not have the capacity to draw down Lake Lemon in a sufficiently short time.

3. Winter rains refill the reservoir before the sediments can be dewatered and Myriophyllum frozen.

4. Temperatures are not cold enough for a long enough period of time to permit freezing Myriophyllum.

The difficulty in overcoming these problems increases from No. 1 to No. 4 above.

Opening the gate to initiate drawdown is the easiest problem to overcome. By opening the gates as soon as possible after Labor Day, the traditional ending of the summer recreation season, the near-shore sediments can be dewatered sufficiently before freezing weather sets in. The effectiveness of this early drawdown is dependent on fall runoff being low enough to not reflood the exposed beds of Myriophyllum.

A greater rate of drawdown could help counter the reflooding potential of the fall and early winter rains. In the past, the gate has not been fully opened although it was opened more during the fall of 1982 than in previous years. According to the U.S. Army Corps of Engineers (1979) the 1.1 meter (42 inch) outlet gate at Lake Lemon has a capacity to release 5.9 m^3/sec (208 ft^3/sec) of water. At this rate, it would take approximately 8 days to lower the water level 0.8 meters (2.5 feet), 15 days to lower the water level 1.5 m (5 ft.), 21 days to lower it 2.3 m (7.5 ft.), and 25 days to lower the lake 3 m (10 ft.)(see Table 8-2). Remember that the Myriophyllum in Lake Lemon is found in water between 0.8 and 3 meters (2.5 - 10 ft.) deep. However, a 3 m drawdown would reduce Lake Lemon's volume by 77% which would be ill advised due to potential adverse biological effects.

These rates of drawdown will be slower if:

1. Additional runoff enters the lake,

2. The gate cannot physically be opened to its maximum,

3. Maximum discharge will erode the downstream channel, thus requiring a less than maximum discharge rate, and/or,

4. The discharge facility is partially blocked by debris.

TABLE 8-2. INCREMENTAL DRAWDOWN TIMES FOR LAKE LEMON

Drawdown of Lake	Incremental Volume of Lake[1]	Time Required (days) to Achieve the Incremental Drawdown for Selected Outflow Rate				
		Outflow Rate[2], (m^3/sec)				
(m)	(10^6 m^3)	1	2	4	6	8
0-0.8	3.9	45	23	11.3	7.5	5.6
0.8-1.5	3.8	44	22	11.0	7.3	5.5
1.5-2.3	3.0	35	17	8.7	5.8	4.3
2.3-3.0	2.5	29	14	7.2	4.8	3.6
3.0-3.8	1.8	21	10	5.2	3.5	2.6
3.8-4.6	1.5	17	9	4.3	2.9	2.2

[1]Total lake volume is 1.7 X $10^7 m^3$.

[2]The stated "outflow rates" represent the actual outflow rate when runoff into the lake is zero or the difference between the actual outflow rate and the total actual runoff rate into the lake.

The rate of discharge through Lake Lemon's outlet is critical, especially if significant runoff and reflooding occur with late fall and early winter rains. If the outlet's capacity is not great enough to prevent exposed sediments from reflooding, the dewatering/freezing cycle will have to start over. This was the case in the fall of 1982 when December rains reflooded the reservoir after it had been drawn down.

The lack of adequate drawdown capacity at Lake Lemon's outlet can be further illustrated by comparing water input to Lake Lemon with the outlet's discharge capacity for the winter drawdown period (Table 8-3). In 1981-82, water input during October - December was low enough to allow a net discharge of water from Lake Lemon via the outlet. However, any drawdown in lake elevation during this period would have been offset by a net gain of water from January - March, the months having the coldest temperatures for damaging exposed

TABLE 8-3. WATER INPUT TO LAKE LEMON VERSUS OUTLET CAPACITY, 1981-2

Month	Input[1] (m^3/mo)	Outlet Capacity (m^3/mo)	Differential[2] (m^3/mo)
Oct 1981	2.66×10^5	1.5×10^7	-1.47×10^7
Nov	3.63×10^5	1.5×10^7	-1.46×10^7
Dec	3.85×10^6	1.5×10^7	-1.12×10^7
Jan 1982	2.23×10^7	1.5×10^7	$+7.3 \times 10^6$
Feb	1.28×10^7	1.5×10^7	-2.2×10^6
Mar	1.62×10^7	1.5×10^7	$+1.2 \times 10^6$

[1]includes surface runoff and direct precipitation from the water budget, Table 5-1.

[2](-) indicates net discharged; (+) indicates net gained
note: lake volume is 1.7×10^7 m^3

macrophytes. For example, if a 1.5 meter drawdown (7.6×10^6 m^3 by volume) was achieved in December (see Table 8-2), January's input of 7.3×10^6 m^3 would nearly fill the lake back up. Events like these have frustrated drawdown management efforts at Lake Lemon in the past.

Supplemental pumping to increase the rate of discharge is possible although the costs may outweigh the benefits. For example, a hydraulic pump with a capacity of 6.5 MGD (0.3 m^3/sec) would increase the discharge rate by approximately 5%. The drawdown times listed in Table 8-2 can be reduced by 5% if such a pump was installed at Lake Lemon.

A local supplier of hydraulic pumps (Bill Cantwell, H.P. Thompson, Cincinnati, Ohio, 1-800-543-4585) recommended two different pump systems. The first is an electric submersible pump, 75-80 horsepower, which would need to be operated from a floating support structure. The pump has a capital cost of about $25,000 and the pump plus floating support could be provided at a total cost of about $35,000. An electrical supply would, of course, need to be provided to the pump and some initial cost would occur during the unit's installation to ensure that the unit remains at its desired location.

A second option for pump selection would be to purchase a portable unit which is totally self-contained and operated from a utility trailer. The unit contains a hydraulic-axial flow pump and a diesel engine, which serves as the power source. As an option, the pump could also be operated from the hydraulic drive unit on a tractor or similar machinery. The entire unit is mobile and could be pulled behind a light-weight truck. The total cost of this package unit, which includes the railer, pump and generator is about $40,000. This unit could operate from above the dam at the access road on the North Side of the dam. A portable, floating intake structure could be used in the water and would cost no more than $5,000.

The cost for the two pump options just described are reasonably similar. The submersible pump option is, however, a permanent installation and would require less preparation before each usage. This option would require a permanent floating intake structure and control facilities. In contrast, the portable unit need not have a permanent floating intake structure but rather the pump, generator and floating intake could be transported to the reservoir on an as needed basis. The portable unit would take a day or two to get into operation and would require considerably more day-to-day supervision and maintenance, in comparison to the submersible pump installation. This disadvantage may be more than offset by the ability of the unit to be moved throughout the area for other uses by the City of Bloomington.

Even if Lake Lemon's problem weed beds remain sufficiently dewatered during the winter, four weeks of freezing weather are necessary for maximum control. Such weather conditions are impossible to control and may not occur each winter. For example, the winter of 1982-83 was so mild that proper freezing of *Myriophyllum* beds probably could not have occurred.

Expected Effectiveness. Lake drawdown is an especially attractive *Myriophyllum* management technique because of its low cost. A 1.5 m (5 ft) drawdown of Lake Lemon would expose approximately 60% of the *Myrophyllum* beds. A successful drawdown combined with freezing conditions can provide effective control of

Myriophyllum for 1-2 years (Cooke 1980). The success of this technique at Lake Lemon can be maximized by opening the outlet gate to its maximum to allow for rapid drawdown and reserve capacity to prevent fall and winter rains from reflooding exposed weed beds. A successful treatment one winter may not have to be repeated the following winter.

Chemical Control

Background and Use. A variety of chemicals are available for aquatic weed control. However, Endothal, Diquat, and 2, 4-D are the chemicals of choice for controlling *Myriophyllum speicatum* (Nichols and Shaw 1982). Their use is reviewed in Table 8-4.

Due to the large costs associated with pesticide development and registration, few new aquatic herbicides have been developed in recent years. There has, however, been considerable research into more efficient use of existing herbicides and herbicide combinations. For example, combinations of herbicides and metal ions have been shown to increase the efficacy of weed control, often with lower concentrations of chemicals used. Endothal and $CuSO_4$ is one such combination (Nichols and Shaw 1982). The use of invert and bivert emulsions of herbicides causes them to adhere to the plants rather than concentrating in the water. Research is also being conducted on the use of slow release formulations of herbicides.

Herbicides are usually most effective at water temperatures above 15-18 ^{o}C, in water with low turbidity, and on young plants (Nichols and Shaw 1982). Application of herbicides after the water has reached 18 ^{o}C and before weeds develop seed is the most effective time to apply herbicides. Regrowth later in the summer or growth of weeds resistant to the initial herbicide treatment may require additional application later in the year.

Possible Negative Impacts. Chemical weed control can directly affect the aquatic environment due to herbicide toxicity or can cause secondary effects due to loss of weeds. Toxicity of herbicides to aquatic life is extremely variable, even for different formulations of the same herbicide (Table 8-4). For example, the amine formulation of endothal and ester formulations of 2, 4-D are much

TABLE 8-4. WEED CONTROL, USE LIMITATIONS, AND FISH TOXICITY OF SOME MAJOR HERBICIDES USED TO CONTROL *MYRIOPHYLLUM*

Use Required	Ortho Diquat[1]	Endothal Dipotassium	2, 4-D Esters	Hydrothal 191 Endothal Amine Salts
Application Rate[2]	1-2 ppmw	2-3 ppmw	2 ppmw	CC[3]
Rate of Kill	Rapid	Rapid	2-6 weeks	Rapid
Use Restrictions Days After Application				
Drinking	10	7	--[4]	7-25
Fishing	10	3	3	3
Swimming	10	1	3	--
Irrigation	10	7	3	14
Fish Toxicity	20 mg/l	100 mg/l	0.6-1 mg/l	0.2-1 mg/l

[1]Label in process of review; use restrictions may be lowered for 1983.
[2]From product labels.
[3]Conditionally controlled.
[4]No value currently available

Source: Nichols and Shaw (1982)

more toxic than are dipotassium endothal or 2, 4-D amines (Nichols and Shaw 1982). Johnson and Finley (1980) summarize the acute toxicity data for pesticides. Direct toxic effects on aquatic life can be minimized by careful selection of herbicides and by proper methods of application. Human use of lakes can be restricted for three days or more following treatment.

Secondary effects related to macrophyte destruction can have a more drastic impact on aquatic life than the herbicide itself. As the weeds die, they release nutrients (phosphorus, nitrogen, etc.) previously tied up in their tissue, into the water. The optimum time for chemical treatment (early summer) is also the worst time for additional nutrients to be added to the water. Increased water temperatures and sunlight at this time, along with increased nutrients from the decaying plants, can be used by algae and non-susceptible macrophyte species for rapid growth. In addition, as treated weeds sink to the bottom and decompose, the increased oxygen demand of the decomposers reduces dissolved oxygen concentrations in the water. This can result in large fish kills in lakes having a heavy growth of weeds and where a fast acting herbicide is used over a large portion of the lake. Finally, decaying vegetation gives off odors that can be objectionable and the plants themselves can be blown onto shorelines by prevailing winds.

Chemical Use on Lake Lemon. Lake Lemon has been treated with aquatic herbicides during the past four years. A local company, Aquatic Control Inc., conducted the treatment using Hydrothol 191 (Mono N, N-dimethal alkal amine endothol), which had been appiled in mass on a four-year cycle with lesser dosages during interim years. Telephone conversations with Bob Johnson of Aquatic Control, Inc. provided the following estimates of acres treated at Lake Lemon. Estimated costs were provided by the City of Bloomington and the Lake Lemon Civic Association.

Year	Hectares Treated	Estimated Cost
1979	97	$ 58,000
1980	13	$ 14,000
1981	2	$ 2,000
1982	14	$ 22,000
TOTAL	126 ha	$96,000

An estimated total of 126 ha were treated over the four year period at a cost of $96,000. This corresponds to an unadjusted average annual cost of $24,000 to treat an average of 32 ha per year.

The estimated annual costs given above were converted to 1982 dollars assuming an interest rate of 12 percent. The investment of $58,000 in 1979 corresponds to nearly $90,000 in 1982 dollars. Similarly, the $14,000 spent in 1980 and $2,000 in 1981 correspond to $17,652 and $2,240 1982 dollars, respectively. Thus, the estimated costs for herbicide treatment in 1982 dollars is as follows:

Year	Estimated Cost-Equivalent 1982 Dollars
1979	$ 89,916
1980	$ 17,652
1981	$ 2,240
1982	$ 23,000
TOTAL	$131,808

Thus, the equivalent of $131,808 1982 dollars have been spent over the period 1979-82. This corresponds to an average annual cost of $32,952 ($1030/ha) based on 1982 dollars. This later annual cost for herbicide treatment is a more accurate cost estimate for comparison purposes in that estimates for the cost of harvesting were obtained for the 1982 calendar year.

Control by Harvesting

Background. Although harvesting includes such methods as raking and pulling macrophytes, and dragging chains through weed beds, our discussion will concentrate on mechanical weed harvesting machines that both cut and remove macrophytes in one pass. The following are some of the advantages of mechanical harvesting:

1. Sustained harvesting (two or more cuts in one year) can reduce the growth of *Myriophyllum* the following year.

2. Organic material removed by harvesting is no longer available to deplete oxygen supplies or recycle nutrients upon decay.

3. Foreign material of a chemical or biological nature is not being introduced into the system.

4. Harvesting costs are competitive with other methods.

5. There is little disruption of lake activities during harvesting.

Possible disadvantages include (Nichols and Shaw 1982):

1. Temporary increase in turbidity.
2. Loss of animal habitat.
3. Potential spread of plants by vegetative means.
4. Increased growth by removing the light-shading canopy.
5. Harvesting of animals.
6. Release of nutrients from cut macrophyte "stumps".
7. Treatment is a relatively slow process.

Application to Lake Lemon. Mechanical harvesting of macrophytes on Lake Lemon should be restricted to deeper water areas free of stumps and other obstructions. Such obstacles can damage the machine's cutting head, resulting in unnecessary "down" time. Areas around piers should be avoided due to the extensive time needed to maneuver the harvester slowly in and around piers. This is the same harvesting strategy used successfully by the City of Seattle on Lakes Washington and Sammamish (Municipality of Metropolitan Seattle 1982).

During the first season of use, the worst areas of Myriophyllum growth should be harvested twice if possible - in June and again in September. In the second season, new areas should be harvested, while allowing enough time to reharvest (once) those areas covered during the first season. Single harvests are often sufficient on areas double harvested the previous season. Late season harvests can be more effective in reducing growth the following season.

The regrowth of Myriophyllum after harvesting decreases when: a) harvests occur later in the growing season, b) multiple harvests are carried out, c) water depth increases, and d) the ratio of cutting depth to water depth increases (Kimbel and Carpenter 1979). These factors should be considered for any Myriophyllum harvesting program implemented at Lake Lemon.

Harvesting Costs. Harvesting options for Lake Lemon have been calculated for a City-owned harvester and for a leased unit. Harvesting costs are based on the specifications of the National Car Rental's MUD CAT Aquatic Weed Harvester Model H7-450 (Table 8-5). It was assumed that a conservative 40 ha/year (100 acres) could be harvested by a two-person crew working 8-hour days, 5 days/week for 10 weeks/year (mid-June to September). More area could be harvested at relatively little additional cost since the capital cost of the harvester is the single largest annual cost. Other assumptions used in calculating costs are outlined in Table 8-6.

The cost of implementing a harvesting program for Lake Lemon (using a purchased machine) has been broken down into five subcategories: (a) labor cost for harvesting, maintenance, and repair of harvester; unloading cuttings; etc; (b) fuel costs for operating the harvester; (c) replacement parts for harvester; (d)

TABLE 8-5. SPECIFICATIONS FOR THE MUD CAT MODEL H7-450

Dimensions:	Length (shipping)	40'6"
	(operating)	38'9"
	Width (shipping)	8'
	(operating)	12'2"
	Height (shipping)	7'8"
	(operating)	10'4"
	Weight (shipping)	9,300 lbs.
Flotation:	Hull Dimensions	24' X 8' X 26" deep
	Hull Material	Sheet steel w/internal bulkheads
	No. of airtight compartments	4
	Draft (empty)	12"
	(max. load)	19"
	Displacement Ratio	2.3" per ton
Power Pack:	Engine	Air cooled diesel
		33 HP @ 3,000 RPM
	Hydraulic Pumps	2
	Hydraulic Reservoir	29 gal.
	Fuel Tank	20 gal.
Harvesting	Cutting Width	7'
Head	Cutting Depth (standard)	5'
	Horizontal Knives	reciprocating
	Impact Absorption	front table retraction system
Load	Storage Capacity	
	-max. volume	400 cu. ft.
	-max. weight	6,000 lbs.
	Unloading Speed	80 sec.
Propulsion:	Drive	2 paddle wheels hydraulically driven, independently reversible
	Paddle Wheels	
	-diam X width	58" X 20.5"
	Paddle Wheel RPM	0 to 40

hauling and disposal of cutting to a nearby landfill and (e) amortization of the initial capital cost of the harvester. The summary of annual costs are as follows:

Labor	$12,000
Fuel	220
Parts	300
Hauling	2,000
Capital Cost of Harvester, Conveyor, and Trailer	11,859
	$26,379 ($659/ha)

Again, these are 1982-dollar cost estimates. As noted previously the annual 1982 adjusted cost of chemical control was $32,952 and, as such, harvesting is cheaper by about $6,500 per year or $371/ha. It is important to note that in many communities which have harvesting programs for weed control, local citizens voluntarily haul the cuttings off site for use in gardens, lawn mulching, composting and the like, thereby saving hauling costs. There is no reason to expect a different response from Lake Lemon's residents and the City of Bloomington could, therefore, save further costs associated with hauling and disposal.

Leasing costs from MUD CAT for the Model H7-450 are based on a rate of 10% of the total capital equipment cost per month for a minimum lease period of three months. For the harvester, trailer, and conveyor, this amounts to 10% of $67,000 or $6,700/month or $20,100 for the minimum 3-month period. A transportation fee of up to $1,500 is required to move the equipment to the site. MUD CAT will train operators, but labor costs are the responsibility of the renter. The summary of leasing costs for a 3-month period are:

Labor	$20,100
Transportation charge	1,500
Fuel	220
Hauling	2,000
Labor	12,000
	$35,820

If the City decides to purchase the harvester following the leasing period, 85% of the lease charge (or $17,085) can be applied towards the purchase price. In this way, the actual leasing charge for the first year would be $3,015.

TABLE 8-6. LISTING OF ASSUMPTIONS USED IN ESTIMATING THE ANNUAL COST OF A HARVESTING PROGRAM FOR LAKE LEMON

- Use MUD CAT Model H7-450 (capital cost: $47,500 in 1983 dollars)
  S-500 conveyor (capital cost: $11,500)
  T-7 Trailer (capital cost: $8,000)

- Machine harvesting rate: 0.4 acres/hr

- Actual harvesting rate: 0.25 acres/hr[1]

- Average daily harvesting yield: 6 yd^3/day[1]
  (Assumes harvested macrophyte biomass of 2 yd^3/acre)

- Fuel usage: 0.5 gallons of diesel fuel/hr

- Life expectancy of harvester: 10 years[2]

- 100% of capital costs financed at 12% interest

- Maintenance: $300/yr (parts only)

- Labor (2-person crew for harvester): $15.00/hr

- Hauling cost (one 6-8 yd^3 truck load/day): $40.00/day

- Disposal cost: 0
  Assumes that a program will be established to allow the public to pick up harvested material, free of charge, to use as compost, mulch, and soil amendments.

[1]Based on harvesting experience of Seattle, Washington.
[2]This is likely a conservative figure.

Controls for Small Areas

Landowners along Lake Lemon have a number of options available to them to control macrophytes around their piers and beaches. These options include hand pulling and bottom covers. Pulling Myriophyllum by hand using rakes can be effective and cost efficient in small areas. Pulling from piers, small boats, or floating tubes has been used.

A new product called the Aqua Weed Cutter (see Appendix I) is now on the market for hand harvesting rooted aquatic macrophytes. With this device, fixed cutter bars on a pole cut a 52" swath through weeds when the cutter is thrown out from a pier or shore and retrieved. Such a device was used by teenagers and property owners to clear Camp's Pond, a small farm pond in Illinois (Camp 1985).

Care must be taken to collect all Myriophyllum fragments pulled or cut since individual fragments can reroot and colonize previously unaffected areas. High school students can be hired to do this work in the summer. The City of Seattle, Washington has organized a coordinated program for hand harvesting. A similar program could be successfully implemented at Lake Lemon.

Screening materials (black plastic, Aqua Screen, etc.) as described in Section 7.3.5 can also provide effective control in small areas around piers and beaches. Non-corrosive mesh screening has been tested by the Wisconsin Department of Natural Resources and such screens have been used on lakes and ponds in 15 states (Engel 1985). When rolled onto a lake bed in spring or draped over grown plants in summer, the screens reduce sunlight and hasten decomposition of underlying vegetation (Figure 8-6). Shorelines, pier areas and boating lanes can remain free of vegetation all summer if screens are used. The screens are easily removed in the fall for cleaning and can be reused the following years.

A final small-area Myriophyllum control can be used in conjunction with lake drawdown. Once Myriophyllum beds are exposed and dry enough to work on, the roots should be raked by hand or tilled by machine to break them up. Research has shown that Myriophyllum stores food reserves in its roots and tubers in the winter. By breaking these up during drawdown, the plants ability to grow again in the spring is greatly reduced. Such control may last

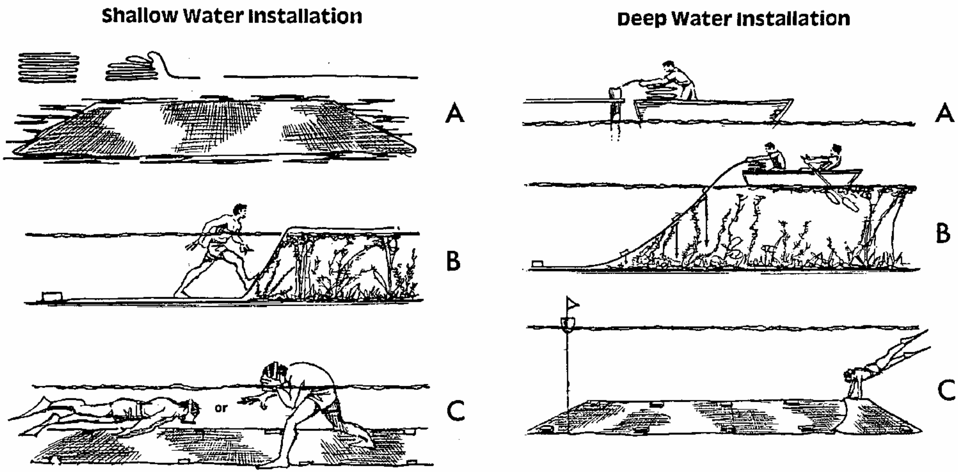

Figure 8-6. Installation methods for aquatic macrophyte screens.

for several seasons and is very cost and labor effective around piers and beaches.

8.3.3 Dredging

The use of dredging as a lake restoration technology at Lake Lemon was considered during the course of this study, however; the technical feasibility of using dredging for macrophyte or sedimentation control was judged to be poor.

Dredging can be used effectively to control macrophytes by increasing water to a depth below the light compensation point required for plant growth. The question is how deep is deep enough? Some species of rooted macrophytes can grow in water as deep as 15 m (Nichols and Shaw 1983). In Lake Lemon, Myriophyllum grows primarily in a zone extending from the shoreline to the 3 m water depth. Deepening this zone to 3+ m by dredging would eliminate nearly all the shallows necessary for fish spawning and swimming.

Shallow water dredging to mechanically remove rooted macrophytes has little lasting impact on the abundance of plants and because dredging equipment is used, it has higher costs and environmental impacts than mechanical harvesting (Nichols and Shaw 1983).

Dredging is routinely used to deepen harbors and navigation channels by the U.S. Army Corps of Engineers and has been used on numerous occasions as a lake restoration method to deepen lakes. In many cases, the goal of lake deepening with dredging is to deepen lakes sufficiently to allow thermal stratification to take place and thereby reduce nutrient recycling from the sediments during the stratified period (Peterson 1981). In Lake Lemon, nutrient recycling from the sediments is not a problem. The sediment problem in Lake Lemon is caused by excessive sediment deposition around the mouth of Beanblossom Creek in the eastern end of the lake. These accumulated sediments do not pose a threat to the lake as a whole but rather, represent a localized navigation problem. Dredging could be used to open up the area for boat navigation but unless upstream watershed management practices are effectively implemented, the area will fill in with sediment again. Dredging would be a short-term control at best without these watershed improvements.

Before a dredging program can be implemented, the following factors must be addressed:

1. The physical and chemical characteristics of the sediments in the area to be dredged must be determined.

2. A sediment disposal area must be identified and designed.

3. A Section 404 Permit to remove sediments is required from the U.S. Army Corps of Engineers.

4. An NPDES Permit from the Indiana State Board of Health is required to discharge water from the sediment disposal area.

Costs for dredging vary widely. In five dredging projects in the Great Lakes Region, the cost range was $0.27 - $2.96 per cubic meter of sediment removed (Peterson 1979). More recent estimates to dredge Cedar Lake, Indiana ranged from $1.60 - $3.30 per cubic meter (Echelberger et al. 1984).

CHAPTER 9: RECOMMENDATIONS AND IMPLEMENTATION

9.1 OVERVIEW

The recommended management plan for Lake Lemon includes a combination of watershed management practices and in-lake controls to manage the major problems at the lake: (a) sedimentation in the eastern end of the lake, (b) shoreline erosion along the lake, and (c) excessive macrophyte growth.

Management of Lake Lemon must consider the various political jurisdictions involved. These include (a) The City of Bloomington, which owns the lake, (b) Monroe County, in which most of the lake lies, and (c) Brown County, which contains most of Lake Lemon's drainage basin. The cooperation and participation of all three of these jurisdictions is essential to the successful implementation of this management plan.

A suggested schedule for implementing this plan is presented in Table 9-1.

9.2 WATERSHED MANAGEMENT COUNCIL

Watershed management is a continuing process requiring the coordination and integration of many diverse activities. Effective watershed management requires more than just best management practices manuals and ordinances; it also requires continual monitoring activities and the cooperation of the residents living in the watershed. For these reasons, we recommend that a Watershed Management Council be formed to coordinate and integrate the management activities at Lake Lemon and its watershed. The Council should be composed of appropriate elected officials from the City of Bloomington, Monroe County, and Brown County; Monroe and Brown County SCS and Cooperative Extension agents; the Lake Lemon Civic Association; and other qualified citizens. This mix would insure that all jurisdictions would be adequately represented. The optimal working size of the council should be 12 or fewer members.

TABLE 9-1. PROPOSED IMPLEMENTATION TIMETABLE - 2 YEAR

Activity	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
											Month													
Form Watershed Management Council	◆	◆																						
Implement Watershed Controls					◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
Mechanical Harvesting						◆	◆	◆	◆									◆	◆	◆	◆			
Conduct Workshops for Homeowners				◆	◆	◆							◆	◆		◆	◆							
Implement Lakeshore Erosion Controls						◆	◆	◆	◆	◆														
Drawdown									◆	◆	◆	◆	◆	◆							◆	◆	◆	◆
Monitoring						◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

A similar approach was used by the City of Charlottesville and Albemarle County in Virginia to coordinate and integrate watershed management activities related to the Beaver Creek Reservoir (Norris 1984). In the Virginia case, a Watershed Management Official was hired and paid for jointly by the two jurisdictions involved. A similar position could be considered for Lake Lemon if the jurisdictions involved agreed to it.

Regardless of the specific arrangement made, it is essential that the City of Bloomington work cooperatively with Monroe and Brown counties to insure that the elements of this management plan are effectively integrated and implemented.

9.3 SEDIMENTATION CONTROL

While the overall sediment deposition rate into Lake Lemon is not excessive, the disproportionate rate of deposition in the eastern end of the lake should be addressed by the management plan. Watershed and streambank erosion controls discussed in Section 8.2 should be implemented where necessary to reduce runoff and erosion in the watershed and thereby limit further deposition of sediment in the lake. Due to the multi-county boundary of the watershed and the specificity of individual watershed management technologies, the identification of site-specific watershed and streambank erosion controls should be determined by the experts at the Soil Conservation Service, a Federal agency with county-level offices in both Monroe and Brown counties.

Indiana law requires a permit before any structural controls (riprap, gabions, etc.) or earthmoving activities (bank grading) are implemented on streambanks or in the floodway of any river or stream with a drainage area greater than one square mile. This requirement would apply to nearly all streams in the Lake Lemon watershed. For more information, contact:

Indiana Department of Natural Resources
Division of Water-Permit Section
2475 Director's Row
Indianapolis, IN 46241
(317) 232-4160

9.4 SHORELINE EROSION CONTROLS

Lakeshore property owners should be required to stabilize shoreline areas where needed to prevent shoreline erosion. Some methods were identified in Section 8.3.1. The City of Bloomington should take a leadership role in this effort. The appropriate City department could serve as a clearing house where lakeshore property owners could receive technical (and possibly financial) assistance in identifying specific problem areas and the appropriate stabilization method to implement. A pamphlet describing typical shoreline problems, stabilization methods, and availability of suitable materials would be useful. See Appendix D for examples.

The use of riprap, shoreline grading, and other shoreline modifications on public freshwater lakes in Indiana may require a permit from the Indiana Department of Natural Resources. Because Lake Lemon is owned and managed by the City of Bloomington, a state permit is not required. However, the Utilities Service Board or the Bloomington Parks and Recreation Department should be contacted before any shoreline modifications are made on Lake Lemon.

9.5 LAKE DRAWDOWN

Lake drawdown in the fall for exposure and drying of Myriophyllum beds should continue, using the guidelines outlined previously in Section 8.3.2. The outlet structure at the dam should be inspected to insure that its rated discharge capacity is achievable. The intake and outlet pipes should be inspected annually and cleaned out when necessary. With the outlet operating at its full capacity (5.9 m^3/sec), a 1.5 m drawdown would take about 15 days, assuming no additional inputs. If this capacity cannot be attained, the outlet structure should be repaired or expanded, or additional pumping capacity installed. The benefits of a successful drawdown versus its low cost make this the most favorable macrophyte control for Lake Lemon.

Drawdown at full outlet capacity should be started as early in September as possible, without interfering with recreational uses. A drawdown of greater than 1.5 m (5 feet) would not be recommended. A 1.5 m drawdown would reduce the lake's volume by approximately 45%

and expose approximately 60% of the *Myriophyllum* beds. Even if climate conditions do not allow optimum control of *Myriophyllum* during drawdown, the additional benefits to Lake Lemon's fisheries and for shoreline repairs justify the efforts and costs involved with lake drawdown.

9.6 DREDGING

Dredging for macrophyte and sedimentation control is not recommended at this time for reasons discussed previously in Section 8.3.3. Shallow water dredging to remove either nutrient sources for macrophytes or to remove the macrophytes themselves has little lasting impact on the abundance of plants. Dredging for removing the accumulated sediment in the extreme eastern end of Lake Lemon would be ill-advised until a comprehensive watershed management program is in place. Once watershed management practices are implemented, dredging could be used to open up the eastern end of the lake for navigation.

9.7 MACROPHYTE HARVESTING

The results of this study do not indicate that phosphorus concentrations in the water column or sedimentation in Lake Lemon are major causes for the excessive macrophyte growth. Therefore, controlling these factors are not anticipated to reduce macrophyte abundance. As long as there is suitable substrate and sufficient light, rooted macrophytes can be expected to grow in Lake Lemon.

Mechanical harvesting of *Myriophyllum* in Lake Lemon is recommended over chemical treatment, especially in the deeper waters, for reasons described previously. Whether a harvester is purchased or leased, or whether harvesting services are contracted out is a decision best made by the city of Bloomington. Mechanical harvesting should be restricted to deeper waters where there are few obstacles to hit and where the harvester can operate most efficiently. Shallow water harvesting with a mechanical harvester is too time inefficient due to its limited maneuverability. Shallow water macrophyte controls are discussed in the following section.

Intensive harvesting (two cuts per year) is recommended for the most heavily-infested areas of Lake Lemon during the first season of use. Cuts in these areas should be made in June and again in September. In the second season, new areas should be harvested, while allowing enough time to reharvest (once) those areas double harvested during the first season. Single harvests are often sufficient on areas double harvested the previous season. Late season harvests can be more effective in reducing growth the following season.

Cut macrophytes should be disposed in areas where runoff from the drying plants cannot drain back into the lake. The City of Bloomington owns a number of lakeshore properties around Lake Lemon where such disposal areas could be located. Once the cut macrophytes are dried, they can be given or sold to gardeners or used by the City Landscape Department.

9.8 SHALLOW-WATER MACROPHYTE CONTROLS

In shallow-water areas where the harvester cannot efficiently operate, the following techniques should be applied: (a) hand pulling with rakes, (b) hand cutting and removing, (c) raking and disruptions exposed _Myriophyllum_ tubers while the lake is drawn down, and (d) using shading/covering materials (Aqua Screen, burlap, black plastic) around piers and beaches (see Appendix I) Chemical control is _not_ recommended. These techniques were described previously in Sections 7.3.5 (p. 175) and 8.3.2 (p. 198). For localized areas, these techniques are relatively inexpensive and can be quite effective. For example, screening materials can destroy 75-95% of plant material within a month (Nichols and Shaw 1982). Screening materials should be removed and cleaned annually.

Lakeshore property owners should be encouraged to actively participate using these methods to control _Myriophyullum_ along their shorelines and around their piers. The City of Bloomington (or Watershed Management Council) could conduct several "how to" sessions each summer or establish demonstration plots to explain the method and materials used. Informational pamphlets would be most useful in describing these alternatives for the lakeshore property owners. See Appendix D for examples.

9.9 ON-SITE SEPTIC SYSTEMS

Lake Lemon beaches are periodically plagued by fecal coliform bacteria levels that exceed the 400 colonies/100 ml water quality standard for full-body contact recreation. Our septic leachate detection survey found significant bacterial contamination (many samples had fecal coliform concentrations too numerous to count) in the Chitwood Addition area and along lower Beanblossom Creek. Contamination was too widespread to pinpoint specific residences as sources. Septic systems in these areas should be inspected by the Brown County Health Department and residents should take care in properly maintaining their systems to prevent continued contamination.

9.10 PROGRAM COSTS

The management program for Lake Lemon as outlined, has the following costs associated with it:

Pump system to supplement drawdown: $35,000

Mechanical harvester, conveyor and trailer: $67,000

Shoreline stabilization: unknown

Watershed management practices: unknown

Septic system maintenance: borne by individual owners

The costs to implement shoreline stabilization and watershed management programs cannot be estimated at this time because site-specific assessments and recommendations were well beyond the scope of this study. Total implementation costs of watershed and shoreline management recommendations will also depend upon the extent that individual landowners participate in the program.

Annual operating costs for the macrophyte harvesting program are estimated to be between $14,000 - $15,000 per year. This includes labor, fuel, parts, and hauling costs. If harvester costs are amortized over a ten year period, annual costs of the mechanical harvesting program would be approximately $26,000 per year.

The major source of revenue to finance the management program for Lake Lemon is expected to be generated from annual lakeshore frontage assessment fees paid by Lake Lemon residents. Additional funds could possibly be generated from Monroe and Brown Counties through the proposed Watershed Management Council, if one is formed. Site-specific watershed management costs are often borne; in part, by the individual land owner.

Funds spent for applicable watershed management practices can often be cost-shared on a 50-50 basis through the Soil Conservation Service. These and applicable in-lake programs may be eligible for 50-50 cost sharing by a Phase II implementation grant from the Environmental Protection Agency's Clean Lakes Program.

CHAPTER 10: MONITORING PROGRAM

As a condition to receiving a Section 314 Clean Lakes Grant from the U.S. Environmental Protection Agency, a monitoring program is required to assess the effectiveness of the restoration efforts. It is recommended that the monitoring program for Lake Lemon comply with guidelines as stated in Paragraph (b) (3), Appendix A of Subpart H to Part 35 of Title 40 - Grants for Restoring Publicly Owned Freshwater Lakes (Federal Register 1979). The complete regulation is presented in Appendix E of this report, however, Paragraph 3 is reproduced here.

> "(3) A Phase 2 monitoring program indicating the water quality sampling schedule. A limited monitoring program must be maintained during project implementation, particularly during construction phases or in-lake treatment, to provide sufficient data that will allow the State and the EPA project officer to redirect the project if necessary, to ensure desired objectives are achieved. During pre-project monitoring activities, a single in-lake site should be sampled monthly during the months of September through April and biweekly during May through August. This site must be located in an area that best represents the limnological properties of the lake, preferably the deepest point in the lake. Additional sampling sites may be warranted in cases where lake basin morphometry creates distinctly different hydrologic and limnologic sub-basins; or where major lake tributaries adversely affect lake water quality. The sampling schedule may be shifted according to seasonal differences at various latitudes. The biweekly samples must be scheduled to coincide with the period of elevated biological activity. If possible, a set of samples should be collected immediately following spring turnover of the lake. Samples must be collected between 0800 and 1600 hours of each sampling day unless diel studies are part of the monitoring program. Samples must be collected between one-half meter off the bottom, and must be collected at intervals of every one and one-half meters, or at six equal depth intervals, whichever number of samples is less. Collection and analysis of all samples must be conducted according to EPA approved methods. All of the samples collected must be analyzed for total and soluble reactive phosphorus; nitrite, nitrate, ammonia, and organic nitrogen; pH; temperature; and dissolved oxygen. Representative alkalinities should be determined. Samples collected in the upper mixing zone must be

analyzed for chlorophyll a. Algal biomass in the upper mixing zone should be determined through algal genera identification, cell density counts (number of cells per milliliter) and converted to cell volume based on factors derived from direct measurements; and reported in terms of biomass of each major genera identified. Secchi disk depth and suspended solids must be measured at each sampling period. The surface area of the lake covered by macrophytes between 0 and the 10 meter depth contour or twice the Secchi disk transparency depth, whichever is less, must be reported. The monitoring program for each clean lakes project must include all the required information mentioned above, in addition to any specific measurements that are found to be necessary to assess certain aspects of the project. Based on the information supplied by the Phase 2 project applicant and the technical evaluation of the proposal, a detailed monitoring program for Phase 2 will be established for each approved project and will be a condition of the cooperative agreement. Phase 2 projects will be monitored for at least one year after construction or pollution control practices are completed to evaluate project effectiveness."

Regardless of whether Federal 314 funds are used to implement the restoration program recommended for Lake Lemon, some monitoring of restoration efforts is strongly recommended and may be essential for the successful restoration of Lake Lemon. Of critical importance is monitoring the extent of Myriophyllum coverage to ascertain whether it is spreading and evaluating regrowth of this species following harvesting. Monitoring the lake for the invasion of new macrophyte and algal species is also recommended, especially if significant control of Myriophyllum is achieved. We also encourage monitoring sedimentation rates in Lake Lemon and recommend that the Indiana Geological Survey duplicate their 1973 sedimentation study as needed or at least every 10-15 years.

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APPENDIX A

WATER QUALITY DATA

Lake Lemon Project Data Summary Sheet

Sample Date October 28/29, 1981

Air Temperature 50° Wind Speed 10

Cloud Conditions 100%, mist Water Color

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	11.0	11.0	11.5	11.5	11.0	11.0	11.0	10.5	11.0	11.0	11.0	7.0	4.5	6.0	6.0	8.0
Dissolved Oxygen (ppm)	8.5	11.2	10.2	10.2	10.0	10.3	10.2	10.1	11.5	11.5	10.8	10.1	10.5	8.4	8.4	10.4
Oxygen Saturation (%)	79	103	96	96	93	96	95	93	106	106	100	85	83	68	68	90
pH	7.5	7.8	7.8	7.8	7.7	7.8	7.7	7.7	8.0	7.9	7.9	7.5	7.6	7.6	7.6	7.9
Alkalinity (mg/l $CaCO_3$)	61	61	60	60	59	60	60	60	61	61	61	119	109	135	155	138
Suspended Solids (mg/l)	24	8	12	11	12	5	10	12	15	7	20	5	3	4	7	10
SRP (μg/l)	10	10	<10	30	<10	<10	<10	<10	<10	10	<10	< 10	<10	10	<10	10
Total P (μg/l)	70	60	180	40	60	60	90	120	50	60	40	30	30	120	40	40
Ammonia (mg/l)	2.1	0.15	0.24	0.30	0.90	0.17	0.08	0.46	2.80	0.80	7.30	0.64	0.02	0.72	0.13	0.12
Nitrate (mg/l)	4.1	2.3	3.7	2.3	1.3	1.3	1.7	2.6	3.7	2.7	4.8	3.2	3.0	1.2	3.4	3.5
TKN (mg/l)	6.7	4.6	5.1	5.0	4.4	4.7	4.7	3.7	7.8	4.9	8.0	3.0	4.2	3.9	3.7	4.2
Chlorophyll a (mg/m³)	13.7	22.8	19.0	14.2	12.4	9.4	14.2	14.0	10.4	14.6	11.8	0.1	0.6	0.5	0.7	0.6
Secchi (cm)		51				43			40							
Fecal Coliform (#/100 ml)	1	2	2	1	2	0	0	1	0	0	0	9	52	109	42	110

Lake Lemon Project Data Summary Sheet

Sample Date Dec. 2/9, 1981

Air Temperature 36°F/32°F   Wind Speed 0/10 mph

Cloud Conditions 100% sleet/ 25%   Water Color

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	6.0	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	4.0	1.0	3.0	2.5	2.5
Dissolved Oxygen (ppm)	P	R O	B E	F A	I L	U R	E —	—	—	—	—	13.1	14.4	13.0	14.4	15.8
Oxygen Saturation (%)	-	-	-	-	-	-	-	-	-	-	-	102	101	101	97	116
pH	7.6	7.9	7.8	7.9	7.7	7.3	7.3	7.3	7.7	7.4	7.2	7.5	7.7	8.0	7.4	7.9
Alkalinity (mg/l $CaCO_3$)	60	60	61	60	60	61	61	61	64	66	65	88	85	109	115	104
Suspended Solids (mg/l)	2	7	3	8	29	27	12	72	24	30	25	5	2	1	12	2
SRP (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	< 10	<10	<10	<10	<10	<10
Total P (µg/l)	50	40	30	40	40	40	40	50	50	60	50	20	10	10	10	20
Ammonia (mg/l)	0.13	0.07	0.10	0.16	0.14	0.08	0.06	0.09	0.08	0.20	0.30	0.11	0.16	0.8	0.38	0.81
Nitrate (mg/l)	2.1	2.7	1.7	2.1	2.6	2.5	2.5	2.3	2.7	3.1	3.0	2.4	0.9	2.7	1.4	2.9
TKN (mg/l)	19.8	33.3	5.3	18.6	14.4	15.8	6.9	2.2	2.2	13	4.9	8.2	18.5	77.1	4.3	9.3
Chlorophyll a (mg/m³)	9.1	8.6	8.3	8.2	8.9	7.0	2.4	6.0	8.7	8.1	7.7	n.d.	n.d.	0.8	0.9	0.6
Secchi (cm)																
Fecal Coliform (#/100 ml)	0	2	0	0	0	0	10	0	0	0	0	0	28	70	50	86

Lake Lemon Project Data Summary Sheet

Sample Date January 20-21, 1982

Air Temperature 30°F ice cover 6-13" Wind Speed 0-5

Cloud Conditions 100% Water Color

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	3.0	2.0	3.0	3.0	3.5	2.0	3.0	4.0	1.0	2.5	3.0	0.5	0.5	0.5	0.5	0.5
Dissolved Oxygen (ppm)	9.2	13.6	11.1	9.7	9.7	12.8	11.0	8.9	12.9	11.3	9.1	13.5	14.3	13.0	13.3	13.8
Oxygen Saturation (%)	69	100	84	74	75	85	83	69	92	85	69	95	101	92	94	98
pH	7.0	7.5	7.8	7.0	6.8	6.9	7.1	7.2	7.2	7.4	7.1	6.9	7.3	7.1	7.5	7.2
Alkalinity (mg/l $CaCO_3$)	59	63	61	60	61	56	55	55	47	47	55	67	55	77	68	68
Suspended Solids (mg/l)	8	14	12	10	8	33	9	4	7	4	12	6	5	10	41	6
SRP (µg/l)	20	<10	10	10	<10	<10	<10	10	<10	<10	<10	<10	10	10	10	20
Total P (µg/l)	40	40	40	50	50	20	50	50	50	70	70	30	10	40	30	30
Ammonia (mg/l)	0.2	0.1	0.2	0.4	0.2	1.6	0.1	0.9	0.2	0.3	1.2	0.1	0.1	0.2	0.2	0.1
Nitrate (mg/l)	EF	1.7	3.0	1.8	1.9	EF	EF	EF	EF	EF	EF	EF	EF	EF	EF	6.9
TKN (mg/l)	EF	EF	EF	EF	EF	EF	EF!	EF	EF	EF	EF	EF	EF	EF	EF	EF
Chlorophyll a (mg/m³)	5.5	-	4.5	6.4	6.6	5.5	4.0	2.9	2.6	5.4	-	-	-	-	-	-
Secchi (cm)		u n	d e r	i c	e											
Fecal Coliform (#/100 ml)	1	0	2	2	0	2	1	0	0	0	3	9	8	48	27	67

Lake Lemon Project Data Summary Sheet

Sample Date February 24, 1982

Air Temperature 38° Wind Speed 0-5

Cloud Conditions 100% Water Color

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	3.0											4.0	3.5	5.0	5.0	5.0
Dissolved Oxygen (ppm)	9.3											12.6	13.0	11.6	12.5	11.9
Oxygen Saturation (%)	70											98	100	93	100	95
pH	6.2				S O F T							6.6	6.3	6.5	6.7	6.5
Alkalinity (mg/l $CaCO_3$)	52				I C E							39	24	39	38	38
Suspended Solids (mg/l)	1											1	3	1	4	1
SRP (μg/l)	EF				N O							20	<10	<10	<10	10
Total P (μg/l)	60				S A M P L E S							50	20	30	60	50
Ammonia (mg/l)	EF				T A K E N							EF	EF	EF	EF	EF
Nitrate (mg/l)	0.8											1.0	1.2	0.4	0.5	0.6
TKN (mg/l)	EF											EF	EF	EF	EF	EF
Chlorophyll a (mg/m^3)	1.0											0	0.1	0.2	0.5	0.1
Secchi (cm)																
Fecal Coliform (#/100 ml)	14											8	28	240	18	72

Lake Lemon Project Data Summary Sheet

Sample Date March 17-18, 1982

Air Temperature 50°F — Wind Speed 5 E

Cloud Conditions 100% — Water Color lake-sandy, tan

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	6.5	8.0	8.0	7.5	7.0	10.0	10.0	8.5	10.0	10.0	10.0	7.0	8.0	8.0	8.0	8.0
Dissolved Oxygen (ppm)	10.8	11.3	11.2	11.0	10.4	10.8	10.8	10.7	10.2	10.2	10.2	11.4	11.4	11.0	11.1	10.6
Oxygen Saturation (%)	90	97	97	94	87	98	98	94	92	92	92	96	99	95	96	100
pH	6.4	6.5	6.8	6.6	6.8	6.6	6.9	6.7	6.5	6.7	6.7	6.5	6.4	6.4	6.5	6.4
Alkalinity (mg/l $CaCO_3$)	28	29	29	29	28	30	31	31	32	32	32	31	22	35	36	26
Suspended Solids (mg/l)	7	1	1	4	2	41	27	21	51	50	47	18	8	33	27	42
SRP (µg/l)	20	20	10	10	<10	<10	<10	60	10	<10	20	20	<10	<10	<10	20
Total P (µg/l)	60	60	50	60	40	100	90	60	150	150	140	30	40	60	50	20
Ammonia (mg/l)	0.10	0.11	<0.1	<0.1	0.12	0.10	0.10	<0.10	<0.10	0.16	0.13	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate (mg/l)	0.69	0.63	0.59	0.60	0.62	0.64	0.88	0.66	0.77	0.85	0.72	0.36	0.76	0.68	0.80	0.74
TKN (mg/l)	0.31	0.58	0.51	0.35	0.34	0.55	0.49	0.23	0.19	0.22	0.17	0.25	0.17	0.36	0.35	0.23
Chlorophyll *a* (mg/m³)	3.9	7.9	6.4	6.0	4.8	7.4	8.5	6.5	4.3	1.8	2.2	0.4	0.8	1.0	1.9	1.1
Secchi (cm)		49				18			12							
Fecal Coliform (#/100 ml)	2	6	6	6	2	168	112	34	210	212	172	12	32	124	80	118

Lake Lemon Project Data Summary Sheet

Sample Date April 13-14, 1982 | Air Temperature 60° | Wind Speed 15-20/0-5

Cloud Conditions clear | Water Color dk green

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	9.5	8.0	8.0	8.0	8.0	8.5	8.5	8.5	9.5	9.5	9.5	6.5	6.0	11.0	10.0	11.0
Dissolved Oxygen (ppm)	11.6	10.2	10.2	10.2	10.8	10.5	10.5	11.1	10.5	10.5	10.5	10.9	11.4	9.8	12.2	12.5
Oxygen Saturation (%)	104	88	88	88	93	92	92	96	95	95	95	91	94	91	110	115
pH	7.1	7.2	7.2	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.2	7.3
Alkalinity (mg/l $CaCO_3$)	32	34	34	34	34	37	37	37	40	40	40	44	30	49	52	43
Suspended Solids (mg/l)	18	6	11	3	11	20	11	14	20	19	24	7	2	12	5	7
SRP (µg/l)	10	10	20	10	10	10	10	10	10	10	10	<10	<10	<10	<10	<10
Total P (µg/l)	50	70	50	40	60	90	80	20	70	100	50	20	20	30	20	30
Ammonia (mg/l)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (mg/l)	1.05	0.69	0.69	0.66	0.73	0.67	0.63	0.62	0.63	0.65	0.63	0.64	0.96	0.79	1.14	0.63
TKN (mg/l)	0.18	0.36	0.31	0.25	0.31	0.26	0.18	0.31	0.23	0.25	0.21	0.22	0.13	0.10	0.12	0.12
Chlorophyll a (mg/m³)	10.2	10.2	13.0	12.4	10.9	8.7	8.3	11.6	7.4	5.5	7.2	0.2	0.4	1.1	1.1	1.6
Secchi (cm)		48				30			30							
Fecal Coliform (#/100 ml)	2	4	4	4	4	0	10	4	14	8	10	22	6	152	44	120

Lake Lemon Project Data Summary Sheet

Sample Date May 5-6, 1982

Air Temperature 70°

Wind Speed 10-15/0-5

Cloud Conditions clear

Water Color dark khaki

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	13.5	20.0	19.0	14.0	13.0	19.0	19.0	14.0	20.0	19.0	14.0	15.0	13.5	17.0	16.0	18.0
Dissolved Oxygen (ppm)	5.4	12.1	12.0	11.8	4.0	11.8	11.9	4.5	10.8	11.1	4.8	9.2	10.1	8.4	10.0	10.3
Oxygen Saturation (%)	53	136	132	117	39	131	131	45	120	122	48	93	99	89	104	110
pH	6.5	8.1	8.1	6.8	7.1	8.2	8.1	6.7	7.7	7.7	6.9	7.1	6.7	6.7	7.1	7.1
Alkalinity (mg/l $CaCO_3$)	35	36	36	35	36	35	38	37	41	40	39	66	51	72	72	67
Suspended Solids (mg/l)	17	16	4	14	19	5	40	10	22	16	36	4	91	15	4	5
SRP (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total P (µg/l)	50	50	20	30	50	30	100	60	40	40	50	10	50	10	20	30
Ammonia (mg/l)	0.14	0.03	0.04	0.05	0.19	0.11	0.05	0.13	0.06	0.07	0.45	0.08	0.07	0.09	0.08	0.09
Nitrate (mg/l)	0.19	0.04	0.09	0.18	0.17	0.11	0.09	0.16	0.07	0.04	0.13	0.07	0.12	0.06	0.22	0.06
TKN (mg/l)	0.55	0.25	0.26	0.26	0.41	0.29	0.31	0.32	0.30	0.24	0.52	0.17	0.16	0.24	0.24	0.26
Chlorophyll a (mg/m³)	10.2	16.7	16.7	13.4	12.4	13.8	10.8	11.0	25.7	21.6	17.2	0.6	0.2	2.8	2.6	3.1
Secchi (cm)		100				-			47							
Fecal Coliform (#/100 ml)	0	0	0	0	4	0	0	6	4	0	10	2	752	82	40	178

Lake Lemon Project Data Summary Sheet

Sample Date May 18-19, 1982

Air Temperature 64° Wind Speed calm

Cloud Conditions 25% — rain Water Color Khacki

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	NO	25.1	23.0	17.0	15.0	24.0	24.0	16.5	23.5	23.5	19.0	17.0	18.8	20.8	20.0	20.8
Dissolved Oxygen (ppm)		8.8	9.5	7.3	0.9	8.8	8.7	1.0	8.1	8.0	0.6	7.6	7.5	5.8	7.7	7.5
Oxygen Saturation (%)	FLOW	108	103	78	13	105	104	14	98	97	16	81	83	67	87	86
pH		8.0	8.2	7.6	6.4	7.9	7.9	6.9	7.4	7.4	6.9	6.8	6.9	6.9	6.7	6.9
Alkalinity (mg/l $CaCO_3$)	THRU	42	42	39	40	43	44	44	45	44	44	107	73	85	75	76
Suspended Solids (mg/l)		1	1	5	7	1	2	1	1	1	7	2	2	10	1	3
SRP (μg/l)	OUT-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total P (μg/l)	LET	20	<10	10	20	10	30	70	10	20	50	40	170	40	30	50
Ammonia (mg/l)		.03	.02	.02	.03	.02	.02	.02	.02	.02	.02	.03	.03	.13	.03	.06
Nitrate (mg/l)		.7	.5	.4	.4	.5	.5	.4	.5	.5	.5	1.3	1.0	1.3	.8	.7
TKN (mg/l)		.32	.29	.29	.35	.31	.27	.27	.21	.24	.36	.15	.23	.35	.29	.27
Chlorophyll a (mg/m³)	-	5.9	8.9	17.1	17.8	6.4	6.5	11.9	10.7	8.0	13.8	1.0	0.7	1.9	1.6	2.8
Secchi (cm)		160				130			75							
Fecal Coliform (#/100 ml)		0	2	0	0	2	0	6	4	0	0	160	1910	400	630	1570

Lake Lemon Project Data Summary Sheet

Sample Date June 1-2, 1982

Air Temperature 60° 68° Wind Speed 5-10/calm

Cloud Conditions 100%/clear Water Color Olive drab

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)		23.0	23.0	20.5	16.0	23.0	23.0	22.5	23.5	23.5	23.5	14.0	15.0	17.0	18.0	17.5
Dissolved Oxygen (ppm)	NO	7.4	7.2	4.5	0.1	6.8	6.8	6.5	7.2	7.2	7.1	9.2	10.2	8.5	9.8	9.4
Oxygen Saturation (%)	FLOW	89	85	51	14	82	82	78	87	87	86	92	103	91	106	101
pH	THRU	7.1	7.1	7.1	6.8	7.1	7.1	7.0	7.1	7.1	7.1	6.7	7.2	7.1	7.0	6.9
Alkalinity (mg/l $CaCO_3$)	OUT-	40	42	45	44	41	36	47	48	47	48	60	48	51	55	45
Suspended Solids (mg/l)	LET	10	10	5	14	14	15	21	25	16	23	1	1	14	23	16
SRP (µg/l)		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total P (µg/l)		<10	<10	<10	10	10	10	<10	10	20	<10	10	10	30	10	30
Ammonia (mg/l)		.03	.04	.04	.35	.07	.07	.08	.03	.03	.04	.04	.04	.05	.03	.05
Nitrate (mg/l)		<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	.15	.11	.2	.2	.3
TKN (mg/l)		.32	.34	.32	.46	.32	.34	.27	.29	.32	.25	.17	.22	.29	.25	.25
Chlorophyll a (mg/m³)	-	8.9	9.9	8.8	7.1	12.5	11.3	10.6	21.3	19.3	18.1	0.8	0.7	1.3	1.0	1.0
Secchi (cm)		95				60			50							
Fecal Coliform (#/100 ml)		12	10	14	0	0	4		20	20	8	30	34	184	252	82

Lake Lemon Project Data Summary Sheet

Sample Date June 16-17, 1982 Air Temperature 60°/52°—65 Wind Speed 0

Cloud Conditions 100% - rain/for clear Water Color khaki

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	24.0	23.0	22.5	22.0	20.0	23.0	22.0	22.0	22.0	22.0	22.0	18.0	19.0	20.5	19.0	20.0
Dissolved Oxygen (ppm)	7.4	7.1	6.9	6.2	0.4	6.7	6.5	6.3	7.0	7.0	6.7	8.4	7.8	6.6	8.0	7.5
Oxygen Saturation (%)	90	85	82	73	16	81	77	75	83	83	79	91	86	75	89	85
pH	6.8	7.1	7.0	6.9	7.0	7.1	7.1	7.1	7.1	7.0	7.0	EF	7.2	7.2	6.8	EF
Alkalinity (mg/l $CaCO_3$)	44	48	48	49	52	51	50	51	53	53	55	89	77	86	82	74
Suspended Solids (mg/l)	13	6	2	13	23	12	5	2	22	4	37	12	64	37	24	99
SRP (μg/l)	10	<10	<10	<10	10	<10	10	<10	10	<10	10	10	10	10	<10	60
Total P (μg/l)	40	20	20	20	30	20	40	30	40	50	60	30	150	60	30	460
Ammonia (mg/l)	<.01	.03	.15	.09	.09	.12	EF	EF	EF	EF	EF	<.01	<.01	.03	<.01	.11
Nitrate (mg/l)	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	.18	1.1	.27	.53	.60
TKN (mg/l)	.28	.30	.33	.27	.30	.32	.32	.25	.32	.26	.28	.25	.29	.28	.22	.74
Chlorophyll *a* (mg/m^3)	8.1	6.3	8.3	7.4	2.4	6.5	9.9	8.2	12.6	13.7	12.3	1.0	1.7	2.0	1.5	2.2
Secchi (cm)		80				55			45							
Fecal Coliform (#/100 ml)	0	6	6	6	0	0	0	0	2	4	0	1024	708	370	264	TNC

Lake Lemon Project Data Summary Sheet

Sample Date July 21-22, 1982

Air Temperature 24-32° Wind Speed 0/0-5

Cloud Conditions hazy sunshine Water Color brownish grey

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	29.0	29.0	28.0	20.0	16.5	28.0	28.0	27.0	27.5	28.0	26.0	22.0	21.0	24.5	23.0	24.0
Dissolved Oxygen (ppm)	8.4	7.9	7.2	0.2	0.1	7.9	7.6	2.0	7.5	5.2	0.2	7.0	7.3	5.9	5.9 5.9	6.0
Oxygen Saturation (%)	112	106	94	15	14	103	100	27	97	67	17	83	84	73	71	73
pH	7.1	7.5	7.3	7.0	6.9	7.3	7.3	7.5	7.4	7.1	7.0	7.0	7.1	7.2	7.1	7.1
Alkalinity (mg/l $CaCO_3$)	53	56	56	72	68	58	58	58	61	59	60	96	84	91	91	97
Suspended Solids (mg/l)	10	4	0	27	20	9	1	2	4	4	11	1	11	27	18	5
SRP (μg/l)	30	<10	<10	20	<10	<10	<10	<10	10	10	20	40	<10	10	<10	30
Total P (μg/l)	40	30	10	40	30	10	10	10	20	10	20	60	30	40	40	70
Ammonia (mg/l)	<0.1	0.07	0.03	0.45	0.51	0.05	0.04	0.05	0.04	0.5	0.10	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrate (mg/l)	.01	0.19	0.30	0.26	0.04	0.03	0.26	0.01	0.01	0.01	0.01	0.20	0.25	0.22	0.19	0.18
TKN (mg/l)	0.36	0.21	0.29	0.21	0.27	0.13	0.13	0.23	0.20	0.18	0.32	0.13	0.24	0.32	0.32	0.29
Chlorophyll _a_ (mg/m^3)	8.2	8.4	8.2	5.6	4.5	10.3	10.8	12.8	13.3	19.1	13.6	0.2	1.9	4.3	2.6	2.1
Secchi (cm)		93				75			50							
Fecal Coliform (#/100 ml)	4	10	4	4	4	2	2	0	2	0		112	154	220	190	104

Lake Lemon Project Data Summary Sheet

Sample Date Aug. 3-4, 1982

Air Temperature 24-27° Wind Speed 0-5

Cloud Conditions ______ Water Color ______

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	28.0	27.0	27.0	21.0	19.0	28.0	28.0	27.0	28.0	28.0	27.5	23.0	23.0	24.0	24.0	24.0
Dissolved Oxygen (ppm)	8.5	6.9	6.9	0.2	0.2	6.9	6.7	4.2	6.9	6.7	6.5	6.9	4.8	5.5	4.6	5.5
Oxygen Saturation (%)	112	90	90	16	15	91	88	54	91	88	84	83	58	68	56	67
pH	7.5	7.3	7.3	6.8	6.7	7.0	7.4	7.2	6.7	6.7	6.7	6.2	6.9	6.9	6.8	6.7
Alkalinity (mg/l $CaCO_3$)	59	59	59	70	83	60	61	60	61	61	61	106	113	109	120	102
Suspended Solids (mg/l)	19	4	14	27	52	15	11	9	17	18	18	6	38	15	28	10
SRP (µg/l)	10	20	10	10	80	10	10	10	<10	10	20	10	10	20	10	20
Total P (µg/l)	50	40	40	80	170	50	50	70	60	60	70	20	50	60	40	40
Ammonia (mg/l)	<0.01	0.04	0.19	0.05	1.20	0.03	<0.01	0.04	< 0.01	< 0.03	0.03	0.05	0.11	0.08	0.08	0.06
Nitrate (mg/l)	<0.01	0.50	0.18	0.82	0.49	<0.01	<0.01	0.12	0.13	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TKN (mg/l)	0.11	0.26	0.27	0.60	0.61	0.29	0.18	0.27	0.19	0.24	0.31	0.08	0.09	0.13	0.18	0.13
Chlorophyll a (mg/m^3)	14.4	16.3	16.8	14.4	14.3	21.0	18.4	19.1	19.4	18.4	21.6	0.6	1.9	15.1	5.1	5.3
Secchi (cm)		75				55			45							
Fecal Coliform (#/100 ml)	0,	80	240	TNC	320	TNC	TNC	TNC	TNC	TNC	TNC	140	208	184	TNC	146

Lake Lemon Project Data Summary Sheet

Sample Date Aug 17-18, 1982

Air Temperature 24° Wind Speed 0-5

Cloud Conditions clear Water Color grey-green

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	25.0	26.0	26.0	23.0	19.0	25.0	25.0	25.0	25.0	25.0	25.0	19.0	20.0	21.0	20.5	20.0
Dissolved Oxygen (ppm)	8.3	7.8	7.7	0.2	0.1	7.8	7.8	4.2	7.6	6.5	6.1	7.4	5.5	5.7	5.2	5.4
Oxygen Saturation (%)	102	99	98	16	15	97	97	52	95	81	76	82	62	66	59	61
pH	8.9	8.3	8.3	7.3	7.1	8.3	8.3	7.8	8.1	8.0	7.9	7.6	7.7	7.6	7.2	7.4
Alkalinity (mg/l $CaCO_3$)	63	62	63	68	88	63	63	63	63	63	63	103	107	109	118	105
Suspended Solids (mg/l)	20	2	10	6	30	6	4	2	26	12	16	22	24	6	14	4
SRP (µg/l)	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Total P (µg/l)	40	30	100	60	110	40	40	40	60	80	60	20	50	50	30	30
Ammonia (mg/l)	0.10	0.04	0.03	0.18	0.62	0.06	0.03	0.04	0.01	0.03	0.04	0.05	0.09	0.12	0.14	0.07
Nitrate (mg/l)	<0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
TKN (mg/l)	1.10	0.18	0.21	0.42	0.51	0.31	0.27	0.40	0.60	0.50	0.30	0.20	0.60	0.50	0.60	0.60
Chlorophyll *a* (mg/m³)	43.0	150.0	43.2	149.7	20.9	150.6	150.6	56.7	151.2	151.1	149.1	0.3	1.1	7.1	4.5	1.7
Secchi (cm)		70				63			35							
Fecal Coliform (#/100 ml)	140	0	0	0	0	0	0	0	0	0	2	70	70	440	260	290

Lake Lemon Project Data Summary Sheet

Sample Date Sept 9-10, 1982

Air Temperature 20-24°C Wind Speed 5-10/0-5

Cloud Conditions overcast → clear Water Color dark khaki

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	22.0	23.0	23.0	23.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	17.0	17.0	19.0	18.0	19.0
Dissolved Oxygen (ppm)	1.4	7.8	7.8	2.6	0.4	7.1	6.8	6.8	7.6	7.2	6.9	8.0	7.2	6.7	7.0	6.9
Oxygen Saturation (%)	18	94	94	31	16	84	80	80	90	85	81	85	77	74	76	76
pH	7.5	8.0	8.0	8.1	7.4	7.8	7.9	7.9	7.9	7.9	7.8	7.5	7.5	7.5	7.3	7.4
Alkalinity (mg/l $CaCO_3$)	69	64	64	64	69	63	-	63	63	63	63	100	96	118	97	94
Suspended Solids (mg/l)	10	4	19	4	33	27	38	19	14	26	1	7	10	42	17	26
SRP (μg/l)	<10	10	<10	10	20	10	<10	<10	10	10	<10	<10	<10	<10	<10	<10
Total P (μg/l)	40	20	20	20	40	30	30	40	50	40	30	20	10	30	20	30
Ammonia (mg/l)	0.27	0.02	<0.01	0.03	0.33	0.03	<0.01	<0.01	0.02	0.02	0.04	0.03	0.02	0.05	<0.01	0.03
Nitrate (mg/l)	1.30	1.20	0.85	1.20	0.88	1.20	0.07	0.96	1.40	2.02	1.00	0.28	0.11	1.30	1.40	1.00
TKN (mg/l)	0.90	0.63	0.57	0.57	0.37	0.68	0.56	0.67	0.73	0.32	0.30	0.12	0.13	0.43	0.24	0.31
Chlorophyll *a* (mg/m³)	21.8	29.9	30.0	14.8	20.3	39.6	42.6	43.8	37.8	48.3	47.0	1.0	1.5	3.2	1.9	3.4
Secchi (cm)		67				38			32							
Fecal Coliform (#/100 ml)	316	0	0	0	0	0	0	0	0	0	0	226	149	230	300	421

Lake Lemon Project Data Summary Sheet

Sample Date October 13, 1982

Air Temperature 12-17° Wind Speed 0-5

Cloud Conditions cloudy - clearing Water Color

Parameter/Sample Site	A	B_1	B_2	B_3	B_4	C_1	C_2	C_3	D_1	D_2	D_3	E	F	G	H	I
Temperature (°C)	18.5	19.0	19.0	19.0	18.5	18.0	18.0	18.0	17.0	17.0	17.0	13.0	12.0	13.0	14.0	13.0
Dissolved Oxygen (ppm)	4.5	5.3	5.0	5.2	4.7	6.8	6.8	6.7	6.6	6.6	6.6	9.6	10.2	6.2	8.1	6.8
Oxygen Saturation (%)	49	59	55	57	52	74	74	73	70	70	70	94	97	61	81	66
pH	7.7	7.6	7.7	7.8	7.9	7.8	7.9	8.0	7.5	7.4	7.6	7.8	7.9	7.6	7.5	7.7
Alkalinity (mg/l $CaCO_3$)																
Suspended Solids (mg/l)	15	12	14	12	13	13	12	17	10	23	27	8	11	15	21	15
SRP (µg/l)			NO		SAMPLES											
Total P (µg/l)	60	50	60	80	50	70	50	60	100	70	210	30	10	110	50	50
Ammonia (mg/l)	NS	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	NS	NS	NS	NS	NS
Nitrate (mg/l)			NO			SAMPLES										
TKN (mg/l)	0.62	0.52	0.47	0.54	0.28	0.40	0.38	0.37	0.36	0.36	0.64	0.35	0.19	0.25	0.26	0.60
Chlorophyll *a* (mg/m³)	5.9	5.4	6.4	4.4	4.9	8.0	8.6	0.9	6.5	6.9	7.8	0	0	1.5	0.4	3.7
Secchi (cm)		65				50			45							
Fecal Coliform (#/100 ml)	NS	0	2	0	0	2	2	0	2	0	0	NS	NS	NS	NS	NS

APPENDIX B

PHYTOPLANKTON BIOMASS DATA

TABLE B-1 Phytoplankton biomass (um^3/ml) at Sampling Site C_1

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Greens													
Actinastrum													123
Ankistrodesmus	576	266	45	30		150	559	188	133	89	89	177	177
Carteria													
Chlamydomonas				25						453			
Chlorococcum			976				694		2,927			732	783
Closteriopsis		857		190				107					
Closterium						121						363	
Coelastrum													
Cosmarium							81	101	1,402	467		872	
Crueigenia								671	413			665	
Golenkinia						8	398						504
Kirchneriella													
Lagerheimia	167	111		12		130			56				
Nephrocytium													
Oocystis								331					
Pediastrum													
Planktosphaeria									6,266				
Pteromonas		2,355										104	
Radioeoccus													
Roya	139										139	836	70
Scenedesmus	584			65		211	58		249	125	125		436
Scherfellia													57
Selenastrum						18							
Staurastrum										3,740	1,247	1,247	
Stylosphaeridium													
Tetrastrum													
Treubaria													
Subtotal	1,466	3,589	1,021	322		638	1,790	1,398	11,446	4,874	1,600	4,996	2,150

TABLE B-1 (continued)

LOCATION C_1

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Blue-greens													
Anabaena							278	1,740	23,925	41,608	24,475	36,592	1,102
Anabaenopsis									2,176	6,746	25,897	9,015	951
Aphanocapsa		302			390	87	2,555		3,847	2,942	4,978	3,847	339
Chroococcus		435	109						22	1,762	2,937	1,524	305
Coelosphaerium							4,044				1,838	5,515	
Gloeothece	187				8								
Gloeotrichia	326									326	652	979	
Lyngbya								3	150	4,365	3,514	3,088	1,331
Merismopedia									87	1,039		779	
Microcystis													
Oscillatoria	2,708	2,499	145		537	4,056	1,047	187	1,959	2,026		10,711	7,526
Raphidiopsis										1,632	2,176		326
Spirulina		5						1		544	3,264	571	286
Subtotal	3,221	3,421	254		935	4,143	7,924	1,931	32,166	62,990	69,731	72,621	12,166
Other													
Ceratium													
Chroomonas		126		39	46	123		121					47
Cryptomonas	30,782	6,840	2,052		83	222							
Dinobryon		12,238	13,698							1,191			
Euglena		34,865	2,012		3,117								
Cymnodinium													
Monomastix			58										
Ophiocytium								31					
Phacus													
Trachelomonas	24,476	6,434		8,579	3,731		995		1,992	1,992		1,992	1,992
Subtotal	55,258	60,503	17,820	8,618	6,977	345	995	152	1,992	3,183		1,992	2,039

TABLE B-1 (continued)

LOCATION C_1

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Diatoms													
Achnanthes						331		199	234	2,571		553	138
Amphora													
Asterionella								462					
Coscinodiscus					816								
Cyclotella	967					238				322		645	484
Cymbella					34	23			35	61	61	2,119	59
Diploneis													
Fragilaria						29							
Gomphoenema			1,074									2,147	
Gyrosigma				492									
Mastogloia													
Melosira	5,431		102	8,929	9,552	1,592	2,683	516	12,042	5,431	8,107	1,810	2,715
Meridion													
Navicula	2,564		909			111			886			2,564	3,846
Neidium													
Nitzchia													
Rhizosolenia		163							245	490		734	
Surirella													
Synedra	11,262	5,198	6,931	1,925	3,978	5,834	630		440	3,465	8,663	35,319	7,364
Subtotal	20,224	5,361	9,016	11,346	14,380	8,158	3,313	1,177	13,882	12,340	16,831	45,891	14,606
Total (C_1)	80,169	72,694	28,111	20,286	22,292	13,284	14,022	4,658	59,486	83,387	88,162	125,500	30,961

TABLE B-2 Phytoplankton biomass (um^3/ml) at Sampling Site C_2

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Greens													
Actinastrum													
Ankistrodesmus	355	118	11	111	225	123	150	716	355	89		89	532
Carteria													
Chlamydomonas													
Chlorococcum								868	3,659	1,464	732	732	1,566
Closteriopsis	1,713	286		71				642					
Closterium					91						363		181
Coelastrum									907				
Cosmarium											467	872	
Crueigenia							41		619				
Golenkinia								1,992			1,008		
Kirchneriella								92					
Lagerheimia	111	222	14		333	333	11						56
Nephrocytium			61										
Oocystis										378			
Pediastrum								563					
Planktosphaeria					1,567			2,331			6,266		
Pteromonas		1,662	52										
Radioeoccus													
Roya	139										697	279	139
Scenedesmus	292				316	789				125			873
Scherfellia													
Selenastrum						27							
Staurastrum										7,479	2,493	1,247	1,247
Stylosphaeridium			1,992										
Tetrastrum				44	66					796			
Treubaria						93							
Subtotal	2,610	2,288	2,130	226	2,598	1,365	202	7,204	5,540	10,331	12,026	3,219	4,594

TABLE B-2 (continued)

LOCATION C_2

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Blue-greens													
Anabaena	1,410				14		278	696	33,778	73,426	44,056	29,555	1,837
Anabaenopsis									1,088	10,607	77,257	17,853	544
Aphanocapsa		302			519		193	4,436	11,088	2,942	14,304	3,168	1,584
Chroococcus		290						152	131	4,699	2,937	1,524	305
Coelosphaerium											3,677	919	919
Gloeothece	158												
Gloeotrichia										326	326	653	
Lyngbya							196	280	287	9,689	5,111	2,023	2,129
merismopedia								432	87	519	1,298		
Microcystis													
Oscillatoria	3,541	1,805			358	7,336	75	374	2,176		6,658	11,868	14,474
Raphidiopsis										4,352	2,720	2,720	
Spirulina		3						3		1,524	2,476	762	
Subtotal	5,109	2,400			891	7,336	742	6,373	48,635	108,084	160,820	71,045	21,792
Other													
Ceratium								16,091					
Chroomonas		252	260	110	46		19						95
Cryptomonas	24,625	5,472	4,617	2,736	83				649				
Dinobryon		10,708	893			629				1,191			
Euglena		24,137	2,012	2,012									
Cymnodinium													
Monomastix													
Ophiocytium						80		61					
Phacus			21										
Trachelomonas	48,951	6,434			12,438	2,488	1,493		1,992	1,992			1,992
Subtotal	73,576	47,003	7,803	4,858	12,567	3,197	1,512	16,152	2,641	3,183			2,087

TABLE B-2 (continued)

LOCATION C_2

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
<u>Diatoms</u>													
Achnanthes						331	53		467	4,207		276	553
Amphora													
Asterionella					1,849								
Coscinodiscus				110									
Cyclotella	645				119	238		156		322	322	322	
Cymbella					169		47		141	182	182	2,119	24
Diploneis													
Fragilaria													
Gomphoenema				358									
Gyrosigma													
Mastogloia													
Melosira	18,102	2,414	1,020	7,796	6,482	2,388	1,032	3,612	28,097	9,051	2,715	1,810	5,431
Meridion													
Navicula			454	2,309						443	886		
Neidium													
Nitzchia													
Rhizosolenia									490	245	1,224	245	245
Surirella													
Synedra	16,460	6,353	3,249	1,155	4,773	11,137	48	121	881	4,332	13,861	37,526	15,923
Subtotal	35,207	8,767	4,723	11,728	13,392	14,094	1,180	3,889	30,076	18,782	19,190	42,298	22,176
Total (C_2)	116,502	60,458	14,656	16,812	29,448	25,992	3,636	33,618	86,892	140,380	192,036	116,562	50,649

TABLE B-3 Phytoplankton biomass (um^3/ml) at Sampling Site C_3

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Greens													
Actinastrum							18						
Ankistrodesmus	355	89		89	470		440	887	355	177		44	155
Carteria													57
Chlamydomonas													
Chlorococcum		1,708	33						732			2,195	3,133
Closteriopsis	857			26	643		286	1,713					
Closterium		181											91
Coelastrum													
Cosmarium							90				467	436	
Crueigenia							275		413			222	95
Golenkinia									1,008				
Kirchneriella													
Lagerheimia	190			12	361		12					56	
Nephrocytium													
Oocystis										189			
Pediastrum			2,597										
Planktosphaeria							4,144			6,266			
Pteromonas		623											
Radioeoccus													
Roya	279										279	279	70
Scenedesmus					316								654
Scherfellia		38											
Selenastrum													
Staurastrum													623
Stylosphaeridium													
Tetrastrum							29						
Treubaria													
Subtotal	1,681	2,639	2,630	127	1,790		5,294	2,600	2,508	6,632	758	3,232	4,878

TABLE B-3 (continued)

LOCATION C_3

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Blue-greens													
Anabaena	1,410							1,392	36,592	51,398	7,343	28,147	1,102
Anabaenopsis									1,088	3,047	39,390	6,187	1,155
Aphanocapsa		75			260		729	12,536	6,788	4,526	679	679	339
Chroococcus								87	44	3,525		305	457
Coelosphaerium										1,838		919	459
Gloeothece	150												
Gloeotrichia									326	326			
Lyngbya	532						249	420	397	6,282	3,407	532	1,224
Merismopedia								864	173				
Microcystis							201						
Oscillatoria	1,250	694			1,431				1,088		2,026	4,342	8,250
Raphidiopsis											1,088	1,632	163
Spirulina		8			1			3	193	381	1,143	381	
Subtotal	3,342	777			1,692		1,179	15,302	46,689	71,323	55,076	43,124	13,149
Other													
Ceratium							7,151						
Chroomonas		95	16	21				97			95		
Cryptomonas	8,208	1,368		1,824	46						649		
Dinobryon		510		290	629		222		1,740				
Euglena							403						
Gymnodinium			11,895							85,665			
Monomastix													
Ophiocytium					159						141		
Phacus	171												
Trachelomonas				4,290	3,731				1,992	3,984	1,992		
Subtotal	8,379	1,973	11,911	6,425	4,565		7,776	97	3,732	89,649	2,877		

TABLE 8-3 (continued)

LOCATION C_3

	12-2-81	1-20-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Diatoms													
Achnanthes					165		118	265	467	2,337	234	276	
Amphora													
Asterionella					462								
Coscinodiscus					272								
Cyclotella	322		54	121					196			322	161
Cymbella					271		364				61	1,413	35
Diploneis													
Fragilaria													
Gomphoenema													
Gyrosigma				492									
Mastogloia													
Melosira	3,621			7,063	13,305		3,899	2,064	8,028	9,051	10,861	3,620	5,883
Meridion													
Navicula			303	3,078									
Navicula													
Neidium													
Nitzchia													
Rhizosolenia									245	245	245		
Surirella													
Synedra	16,461	5,776	1,733	1,155	6,364		54		1,542	6,931	6,931	17,659	9,097
Subtotal	20,404	5,776	2,090	11,909	20,839		4,435	2,329	10,478	18,564	18,332	23,290	15,176
Total (C_3)	33,806	11,165	16,631	18,461	28,886		18,684	20,328	63,407	186,168	77,043	69,646	33,203

TABLE B-4 Phytoplankton biomass (um^3/ml) at Sampling Site G (Beanblossom Creek)

	12-2-81	1-20-82	2-24-82	3-17-82	5-18-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
<u>Greens</u>												
Actinastrum												
Ankistrodesmus	5	6		3	31	4	9	37	15	15		
Carteria												
Chlamydomonas									91			
Chlorococcum											146	
Closteriopsis			36				1,332					
Closterium												
Coelastrum												
Cosmarium								51				
Crueigenia								83		165		
Golenkinia									5			
Kirchneriella												
Lagerheimia			7									
Nephrocytium												
Oocystis								68				
Pediastrum												
Planktosphaeria												
Pteromonas			14									
Radioeoccus												
Roya								28				
Scenedesmus					12				14			21
Scherfellia												
Selenastrum												
Staurastrum												
Stylosphaeridium												
Tetrastrum												
Treubaria	1,275											
Subtotal	1,280	6	57	3	43	4	1,341	267	125	180	146	21

TABLE B-4 (continued)

LOCATION G

	3-17-82	4-13-82	5-05-82	6-16-82	6-29-82	7-21-82	8-3-82	8-17-82	9-8-82	10-13-82
Blue-greens										
Anabaena					29,610			37	22	
Anabaenopsis								35		
Aphanocapsa										
Chroococcus										
Coelosphaerium							435			
Gloeothece										
Gloeotrichia										
Lyngbya				41			27	27	27	
merismopedia										
Microcystis										
Oscillatoria						54			54	54
Raphidiopsis										
Spirulina										
Subtotal				41	29,610	54	462	99	103	54
Other										
Ceratium										
Chroomonas										38
Cryptomonas	211		439	121						1,358
Dinobryon		476								
Euglena						34				
Cymnodinium										
Monomastix										58
Ophiocytium										
Phacus										
Trachelomonas		2,574	3,217	7,721				1,931		
Subtotal	211	3,050	3,056	7,842		34		1,931		1,454

TABLE B-4 (continued)

LOCATION G

	12-2-81	1-20-82	2-24-82	3-17-82	4-13-82	5-5-82	5-18-82	6-16-82	6-31-82	7-21-82	8-4-82	8-18-82	9-8-82	10-13-82
Diatoms														
Achnanthes								623	346	103				
Amphora						655			616	504				
Asterionella														
Coscinodiscus														
Cyclotella														
Cymbella							44	1,132		1,767	109		560	
Diploneis										519				
Fragilaria														
Gomphoenema				1,197	997	2,493	1,662		810	61			859	
Gyrosigma												6,233		92
Mastogloia									323					
Melosira									261,075	2,754	2,198	550		
Meridion				168		831								
Navicula			31	262		3,272	8,726	11,432	3,314	3,116	374	1,496	7,180	4,103
Neidium														
Nitzchia														
Rhizosolenia														
Surirella								2,909	1,616	727			1,455	
Synedra	650	507		7,800	2,026	16,379	11,443	24,323	10,056	6,094	173	866	5,470	3,039
Subtotal	650	507	31	9,427	3,032	23,630	21,875	40,419	278,156	15,645	2,854	9,145	15,524	7,234
Total (G)	1,930	513	88	9,641	6,073	27,286	21,918	48,306	309,107	16,000	3,441	11,355	15,773	8,763

APPENDIX C

LAKE LEMON FISHERIES SURVEY REPORT

LAKE LEMON

1982 FISH MANAGEMENT REPORT

Paul A. Glander
Fisheries Technician

FISHERIES SECTION
INDIANA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
607 State Office Building
Indianapolis, Indiana 46204

1983

LAKE LEMON
Monroe and Brown Counties

Fish Management Report
1982

INTRODUCTION

Lake Lemon is a 1,440 acre impoundment located on Bean Blossom Creek in Monroe and Brown Counties, northeast of Bloomington. The lake was constructed and is owned by the city of Bloomington as part of its water supply system. Since Lake Monroe has become the primary water source, Lake Lemon has been used mostly for recreation. The Bloomington-Monroe County Parks and Recreation Department operates camping and day-use facilities at Riddle Point Park, including a single lane boat launching ramp. A permit is required to use this ramp and to operate a boat on Lake Lemon. The permit costs $3.00 per day or $20.00 per year for non-motorized boats and $6.00 daily or $40.00 yearly for motor boats. The two marinas on the lake charge a fee for use of their launching ramps. Boaters using these ramps must also purchase a daily or annual boating permit. All of the shore line, except the park, is privately owned. Assessments collected from lakeshore landowners and money from the boating permits are used for control of aquatic plants in the lake.

Rapid sedimentation and overabundance of aquatic plants (mostly eurasian water milfoil) have been problems at Lake Lemon. Bean Blossom Creek carries a large sediment load. Much of this sediment is deposited in the eastern basin of Lake Lemon. Water milfoil grows over most of lake less than ten feet deep, hindering swimming, boating and fishing. Indiana University conducted a study in 1982 to scientifically identify the lake's problems and recommend stratigies to correct them. The Department of Natural Resources was asked to conduct a fisheries survey to provide data about the fish community. This was an initial fisheries survey. No other information about the fish community or fish stocking history is available.

METHODS AND RESULTS

Submerged aquatic plants were not as abundant during the September 27 to October 1 survey as during the summer. Chemical weed control and the natural fall die-off had reduced the coverage of milfoil. Emergent plants and algae occurred only in small area and were not a problem for fishing.

Indiana University personnel provided water chemistry data from a September 10, 1982 sample taken at the middle of the lake. On this date and on September 27 the lake was not stratified. The water temperature was roughly similar from surface to bottom. Dissolved oxygen was sufficient to support game fish in the upper ten feet of the lake and probably deeper. Although total alkalinity was somewhat low, both it and pH were within the normal range for lakes in south-central Indiana.

Survey effort consisted of D.C. electrofishing for 3.46 daylight hours and 2.31 hours after dark. Experimental mesh gill nets were fished for 384 hours and trap nets for 144 hours. Fish collected were measured to the nearest 0.1 inch in total length and weighed to the nearest 0.01 pound. Scale samples were taken from a subsample of the fish for age and growth determination. The fishery was evaluated by comparing this length, weight and growth data to similar information collected at other southern Indiana lakes.

A total of 3,049 fish weighing 766 pounds and representing 20 species was collected. Gizzard shad comprised almost half (49%) of the number of fish collected. Bluegill was the second most abundant species by number (20%) followed by white crappie (8%), golden redhorse (7%), largemouth bass (5%), and yellow bass (3%). Channel and flathead catfish, redear sunfish, spotted bass, carp, yellow perch, golden and spotfin shiners, logperch, warmouth, brook silverside, spotted and white suckers and yellow bullhead comprised the remaining 9%.

Gizzard shad ranked first by number (49%) and third by weight (18%). A total of 1,479 shad was collected. They ranged from 3½ to 1[illegible] inches long. Over 80% of the shad were one or two years old and 5 to 7 inches long. Growth of shad older than age 1 was below average. A slow growing shad population can be an asset because the shad stay vulnerable to predation for a longer time. However, at Lake Lemon, the abundance of slow growing shad is a disadvantage. Numerous small shad dilute the positive effects of predation on small panfish which are overabundant in Lake Lemon. Shad also compete with young game fish for zooplankton which are small fish food organisms.

Bluegill were the most abundant game fish, forming 20% of the collection by number. Bluegill ranged from 1½ to 7 inches long. About 25% of them were considered catchable (longer than 6 inches). Growth of bluegill was below average. Age 1 bluegill were 3 to 4 inches long. Age 3 fish were 4½ to 5 inches and age 5 bluegill were 6 inches or larger. Average weights of bluegill were similar to district means for fish smaller than 5 inches but below average for larger fish.

A total of 249 white crappie was collected. Only 4% of the crappie were catchable size (longer than 8½ inches). Almost 90% of the crappie were 5 to 6½ inches long. These were one and two year old fish spawned in 1980 and 1981. Crappie growth was below average. Average weights of crappie smaller than 9 inches were at or slightly below district averages. The average weights of 10 to 11½ inch crappie, those able to utilize the abundant forage, were about average.

Golden redhorse formed 6% of the total number of fish collected, but 26% of the total weight. Over 90% of the redhorse collected were longer than 12 inches. Golden redhorse usually live in streams, so those collected in Lake Lemon were probably spawned in Bean Blossom Creek.

Largemouth bass accounted for 5% of the collection by number and 15% by weight. They ranged from 3 to 19 inches long. Twenty percent of the largemouth bass were 14 inches or longer. Growth of largemouth bass was slightly below the district average for fish less than three years old. Older bass grew at average or above average rates. These fish were able to better utilize the forage in Lake Lemon. Average weights showed a pattern similar to growth rates. Average weights were about equal to district averages for fish less than 12 inches, but above average for larger bass.

A total of 91 yellow bass was collected. Almost 90% of these fish were 5½ to 7 inches long, from the 1981 year class. The yellow bass in Lake Lemon were growing faster than those in Lake Monroe (Andrews, Personal communication). However, yellow bass are more abundant in Lake Monroe and intraspecific competition has slowed their growth (Ball, 1981).

Channel catfish accounted for 2% of the sample by number and 8% by weight. They ranged from 7½ to 28 inches long. About half the catfish were harvestable size (12 inches or longer). Although no catfish were aged, their length frequency distribution indicated that they were reproducing in the lake or Bean Blossom Creek. The average weights of catfish less than 17½ inches long were below district averages.

All redear sunfish collected were a harvestable size of 6 inches or longer. This was due to the absence of redear younger than age 4 which also indicates poor reproduction after 1978. The redear were slow growing. Age 5 fish were only 6 to 7 inches long. Average weights were below district averages.

Spotted bass are less common in Lake Lemon than largemouth bass, but do ocassionally show up in a fishermen's catch. They usually do not grow as large or as quickly as largemouth bass. A total of 34 spotted bass was collected. They ranged from 3 to 12½ inches long. Four-year-old spotted bass were 9½ inches long and larger.

Carp accounted for only 1% of the collection by number but 18% by weight. A total of 83 was collected. No carp less than 16 inches long were collected. The largest carp was 27½ inches and weighed over 10 pounds. Although most of the carp were not aged, examination of scales from several fish indicated that they were growing slowly.

DISCUSSION AND SUMMARY

The fish community in Lake Lemon is dominated by non-game species. Gizzard shad, golden redhorse and carp accounted for over 50% of the collection by number and more than 60% by weight. All the carp, most redhorse and many shad were too large to be vulnerable to predation. Thus, much of the fish biomass in Lake Lemon is not being utilized by anglers or as food for other fish.

The bluegill and white crappie populations are composed of many small, slow-growing fish. Competition for food among these species, redear sunfish and yellow bass is keen and results in slow growth. When bluegill in Lake Lemon reach harvestable size, many of them are five years old and dying of natural causes. Slow panfish growth rates are an indication that panfish populations are close to the limit of what the lake can support.

Large, predatory fish such as largemouth and spotted bass, channel and flathead catfish and larger crappie are able to utilize the abundant forage base and are growing normally. Conversely, smaller individuals of these species are growing at a slower rate.

One factor affecting the Lake Lemon fish community is the overabundant aquatic plants. Plants provide cover for small fish to escape predation. This increases the survival of prolific prey species. Competition among the overabundant survivors is strong, and results in slow growing fish.

RECOMMENDATIONS

The annual fall and winter drawdown should be continued. Drawdowns concentrate the fish and increase predation on small to medium size shad and panfish. This may lead to faster growing and larger bluegill, crappie and redear. In a lake as shallow as Lemon a drawdown of only a few feet will reduce the surface area significantly. The longer the lake is held at the lower level the greater the possible benefits. Drawing Lake Lemon down more than 5 to 10 feet is unnecessary and could cause a winterkill of fish.

Aquatic plant control should be conducted yearly by the Bloomington-Monroe County Parks and Recreation Department. This will make boating and fishing easier and may benefit the fish community by increasing predation on small fish. Alternatives to chemical weed control, such as mechanical harvesters or "Aquascreen" used in localized areas, may be more cost effective.

Stocking of additional native fish into Lake Lemon is not warranted as the existing populations are suspected to be close to what the lake can support. Additional predators, such as northern pike, walleye or muskellunge might thin rough fish and panfish populations slightly, but not enough to make a noticable improvement in game fish growth rates.

However, if white bass could be established in the lake, they would have a positive, though probably small, influence on the fishery. White bass are effective predators and they could naturally reproduce in Lake Lemon. The primary advantage of white bass is that they could provide a new game fish fishery at a relatively low cost. It is recommended that the Division of Fish and Wildlife stock 5-700 adult white bass in the spring of 1984. A spring stocking would allow the white bass to spawn that year in Lake Lemon and possibly create a large year class of young fish. A spot-check survey should be conducted during 1986 to determine if the introduction was successful.

Best fishing opportunities in Lake Lemon are for largemouth bass, channel and flathead catfish and a few large white crappie. Many small bluegill, white crappie and yellow bass will be available to anglers.

Submitted by: Paul A. Glander, Fisheries Biologist
Date: April 13, 1983

Approved by: Thomas M. Flatt
Thomas M. Flatt, Fisheries Supervisor

Approved by: William D. James
William D. James, Chief of Fisheries
Date: October 17, 1983

LITERATURE CITED

Ball, R.L. 1981. Changes in Yellow Bass Growth Rates and Density During the First Ten Years of Its Establishment in Monroe Reservoir. Proceedings of the Indiana Academy of Science, 1980. 90:190. Abstract only.

/x/ INITIAL SURVEY

/ / RE-SURVEY

/ / OTHER

LAKE Lemon

COUNTY Monroe-Brown

BIOLOGIST Paul Glander

DATE OF SURVEY Sept. 27 - Oct. 1, 1982 DATE OF APPROVAL ______

1. QUADRANGLE NAME Hindustan, Morgantown TWP. 10N R. 1E S.27,28,33,34,35, 36,31

2. NEAREST TOWN Trevlac

3. ACCESSIBILITY - STATE OWNED PUBLIC ACCESS SITE: None
   PRIVATELY OWNED PUBLIC ACCESS SITE: 2 privately owned marinas, sailing cl
   OTHER: Bloomington City Park at Riddle Point launching site

4. SURFACE ACRES 1,440 MAXIMUM DEPTH 28 (FT.) AVERAGE DEPTH - (FT.) ACRE FT. -

5. WATER LEVEL 630 ft. (MSL) EXTREME FLUCTUATIONS Annual fall and winter drawdown

6. LOCATION OF BENCHMARK Along South Shore Drive near east end of lake

7. INLETS:

   NAME Bean Blossom Creek LOCATION East end of lake ORIGIN R2E, T 10N, S 25

   NAME Shuffle Creek LOCATION South side of lake ORIGIN R1E, T 9N, S 4

   NAME ______ LOCATION ______ ORIGIN ______

8. OUTLET:

   NAME Bean Blossom Creek LOCATION West end of lake

9. WATER LEVEL CONTROL Outlet works and spillway (42" diameter outflow tube)

10.

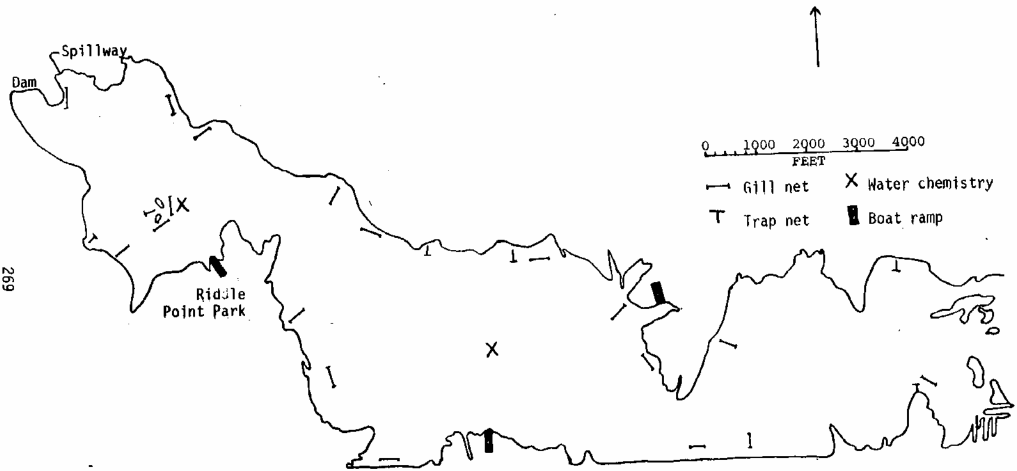
POOL	ELEVATION (FEET MSL)	ACRES
TOP OF DAM	-	
TOP OF FLOOD CONTROL POOL	-	
TOP OF CONSERVATION POOL	-	
TOP OF MINIMUM POOL	-	
STREAMBED	-	

11. BOTTOM TYPE: BOULDER ___ GRAVEL ___ SAND X MUCK X CLAY X MARL ___

12. WATERSHED USE: State forest, agriculture, pasture, residential

13. DEVELOPMENT OF SHORELINE: Numerous homes and cottages, two marinas, city park

14. PREVIOUS SURVEYS AND INVESTIGATIONS: Diagnostic feasibility study by Indiana University, 1982. Sedimentation study, Indiana Geological Survey, 1973.



MAP OF LAKE LEMON

15. SAMPLING EFFORT:

ELECTROFISHING:	DAY HOURS 3.46	NIGHT HOURS 2.31	TOTAL HOURS 5.77
GILL NETS:	NUMBER 16	HOURS 24	TOTAL HOURS 384
TRAPS:	NUMBER 6	HOURS 24	TOTAL HOURS 144

SHORELINE SEINING: NUMBER OF 100 FOOT SEINE HAULS None

ROTENONE: GALLONS None ppm ACRE FEET TREATED

PHYSICAL AND CHEMICAL CHARACTERISTICS

16. COLOR Clean green to muddy brown TURBIDITY 3 FT. 2 INCHES (SECCHI DISK

17. TEMPERATURE:

DEPTH	DEGREES F. Sept. 27	Sept. 10	DEPTH	DEGREES F
SURFACE	64	75	40	
2	64		42	
4	64		44	
6	64	75	46	
8	64		48	
10	64		50	
12	64		52	
14	63	75	54	
16	63		56	
18	63		58	
20 Bottom	63		60	
22			62	
24			[illegible]	
26			66	
28			68	
30			70	
32			72	
34			74	
36			76	
38			78	

18. D.O. - TOTAL ALKALINITY - pH:

DEPTH	D.O.	TOTAL ALKALINITY	pH
SURFACE	7.1 ppm	63	7.8
5			
10	6.8 ppm	63	7.9
15			
20			
25			
30			
35			
40			

LIMIT OF THERMOCLINE: No obvious thermocline

WATER SAMPLE IDENTIFICATION SHEET

Sample Site Lake Lemon
East Basin

Station Number

Sample Date 1 (Mo. 11-12) 20 (Day 13-14) 83 (Yr. 15-16) AM (AM/PM)

Supervisor

Collector(s) Paul Glander

Delivered to lab 1 (Mo.) 20 (Day) 83 (Yr.) PM (AM/PM)

By Paul Glander

	Kind	Lot No	Amount
Preservatives Added:	NONE		

Sample Chlorinated ____ Not Chlorinated ✓

	Field	Lab
No. of 1 Liter Plastic Bottles		
No. of 2 Liter Plastic Bottles	1	
No. of Bacteriological Bottles		
No. of Glass Jars or Bottles		
Total		

Standard Procedure Followed All Some None

NPDES Number ____ (1-7) Outfall ____ (8-10)

1 (17)
1. NPDES
2. SPC-15
3. WQ Study
4. Pollution complaint
5. Fish kill investigation

✓ (18)
1. Industry
2. Semi-Public
3. Municipal
4. Federal
5. Public Water Supply
6. State operation
7. Other

____ (19) Sample Type
1. Grab
2. 24-hour comp.
3. 8-hour comp.
4. 24-hour flow comp.
5. 8-hour flow comp.

____ (20) Sample Interval

____ (21)
0 - at outfall
1 - above outfall
2 - below outfall

____ (22-26) Stream miles from outfall

LAB INFORMATION

Lab No. D0174 Date JAN 20 1983 12:30 (Mo. Day Yr. AM/PM)

Rec'd by DB

Temp of samples when received

CODE	PARAMETERS	UNIT		LAB DATA
28-32 00410	Alkalinity Total $CaCO_3$	mg/l	✓	34-41 50.
00610	Ammonia-N	mg/l	✓	<0.1
01002	Arsenic	ug/l		
00310	BOD_5	mg/l		
01027	Cadmium	ug/l		
00940	Chlorides	mg/l		
01032	Chromium-Hex	ug/l		
01034	Chromium-Tot	ug/l		
00335	COD	mg/l		
01042	Copper	ug/l		
00720	Cyanide-CN	mg/l		
00951	Fluoride	mg/l		REPORTED
01045	Iron	ug/l		1 10 1983
01051	Lead	ug/l		DB
01055	Manganese	ug/l		WATER LABORATORY
71900	Mercury	ug/l		STATE BD. OF HEALTH
01067	Nickel	ug/l		
00630	NO_2+NO_3-N	mg/l	✓	0.7
00550	Oil & Grease	mg/l		
00403	pH (lab)	S.U.	✓	7.3
32730	Phenol	ug/l		
00665	Phosphorus-P	mg/l	✓	0.03
00530	Solids - Susp	mg/l		
00500	Solids (total)	mg/l		
00945	Sulfate	mg/l		
00625	TKN	mg/l		
00680	TOC	mg/l		
01092	Zinc	ug/l		
31616	Fecal coliform	100 ml		

Comments: Send Results To
Paul Glander, Fisheries Biologist
Avoca State Fish Hatchery, PO Box 16

SBH65-030

WATER SAMPLE IDENTIFICATION SHEET

Sample Site Lake Lemon
Riddle Point

Station Number

Sample Date 1 (Mo. 11-12) 20 (Day 13-14) 63 (Yr. 15-16) AM (AM/PM)

Supervisor

Collector(s) Paul Glander

Delivered to lab 1 (Mo.) 20 (Day) 63 (Yr.) PM (AM/PM)

By Paul Glander

	Kind	Lot No.	Amount
Preservatives Added:	NONE		

Sample Chlorinated ____ Not Chlorinated ✓

	Field	Lab
No. of 1 Liter Plastic Bottles		
No. of 2 Liter Plastic Bottles	1	
No. of Bacteriological Bottles		
No. of Glass Jars or Bottles		
Total		

Standard Procedure Followed All Some None

NPDES Number ____ (1-7) Outfall ____ (8-10)

1 (17)
1. NPDES
2. SPC-15
3. WQ Study
4. Pollution complaint
5. Fish kill investigation

6 (18)
1. Industry
2. Semi-Public
3. Municipal
4. Federal
5. Public Water Supply
6. State operation
7. Other

____ (19) Sample Type
1. Grab
2. 24-hour comp.
3. 8-hour comp.
4. 24-hour flow comp.
5. 8-hour flow comp.

____ (20) Sample Interval

____ (21)
0 - at outfall
1 - above outfall
2 - below outfall

____ (22-26) Stream miles from outfall

LAB INFORMATION

Lab No. D0173 Date JAN 20 1983 12:30 (Mo. Day Yr. AM/PM)

Rec'd by 03

Temp of samples when received

Comments: Send Results To
Paul Glander, Fisheries Biologist
Avoca State Fish Hatchery, PO Box 16
Avoca IN 47420

CODE	PARAMETERS	UNIT		LAB DATA
28-32 00410	Alkalinity Total $CaCO_3$	mg/l	✓	34-41 48
00610	Ammonia-N	mg/l	✓	<0.1
01002	Arsenic	ug/l		
00310	BOD_5	mg/l		
01027	Cadmium	ug/l		
00940	Chlorides	mg/l		
01032	Chromium-Hex	ug/l		
01034	Chromium-Tot	ug/l		
00335	COD	mg/l		
01042	Copper	ug/l		
00720	Cyanide-CN	mg/l		
00951	Fluoride	mg/l		
01045	Iron	ug/l		
01051	Lead	ug/l		
01055	Manganese	ug/l		
71900	Mercury	ug/l		
01067	Nickel	ug/l		
00630	NO_2+NO_3-N	mg/l	✓	0.7
00550	Oil & Grease	mg/l		
00403	pH (lab)	S.U.	✓	7.1
32730	Phenol	ug/l		
00665	Phosphorus-P	mg/l	✓	0.04
00530	Solids - Susp	mg/l		
00500	Solids (total)	mg/l		
00945	Sulfate	mg/l		
00625	TKN	mg/l		
00680	TOC	mg/l		
01092	Zinc	ug/l		
31616	Fecal coliform	100 ml		

REPORTED
1983
03
WATER LABORATORY
IND. STATE BD. OF HEALTH

SBH65-030
State Form 1490

19. COMMON SPECIES OF AQUATIC PLANTS

COMMON NAME	SCIENTIFIC NAME	DEPTH FOUND	PER CENT COVERED
Submergent			
Eurasian water milfoil	Myriophyllum spicatum	2-10 feet	10
Emergent			
Common cattail	Typha latifolia	0- 2 feet	1
Common arrowhead	Sagittaria latifolia	0- 2 feet	1
Smartweed	Polygonum sp.	0- 1 foot	2
Water willow	Salix sp.	0- 2 feet	2
Algae			
Filamentous algae		Surface	!1

COMMENTS Milfoil coverage is much greater in mid-summer. Emergent forms common only in bays and channels.

FISHES

20. SPECIES AND RELATIVE ABUNDANCE BY NUMBER AND WEIGHT

COMMON NAME	SCIENTIFIC NAME	NUMBER	(%)	WEIGHT (LBS.)	(%)
Gizzard shad	Dorosoma cepedianum	1,479	48.5	135.87	17.7
Bluegill	Lepomis macrochirus	604	19.8	50.99	6.7
White crappie	Pomoxis annularis	249	8.2	18.57	2.4
Golden redhorse	Moxostoma erythrurum	198	6.5	200.90	26.2
Largemouth bass	Micropterus salmoides	154	5.1	114.61	15.0
Yellow bass	Morone mississippiensis	91	3.0	8.94	1.2
Channel catfish	Ictalurus punctatus	65	2.1	59.94	7.8
Redear sunfish	Lepomis microlophus	46	1.5	6.96	0.9
Spotted bass	Micropterus punctalatus	34	1.1	9.89	1.3
Carp	Cyprinus carpio	33	1.1	138.15	18.0
Yellow perch	Perca flavescens	28	0.9	1.62	0.2
Golden shiner	Notemigonus crysoleucas	14	0.5	1.93	0.3
Logperch	Percina caprodes	14	0.5	0.67	0.1
Warmouth	Lepomis gulosis	13	0.4	1.38	0.2
Flathead catfish	Pylodictis olivaris	10	0.3	7.49	1.0
Brook silverside	Labidesthes sicculus	7	0.2	0.05	*
Spotted sucker	Minytrema melanops	3	0.1	4.97	0.6
White sucker	Catostomus commersoni	3	0.1	3.08	0.4
Spotfin shiner	Notropis spilopterus	3	0.1	Trace	*
Yellow bullhead	Ictalurus natalis	1	*	3.08	*
Totals:		3,049		766.36	

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF GIZZARD SHAD

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
3.5	1	0.1	.02	0+
4.0	1	0.1	.03	0+
4.5	2	0.1	.04	0+
5.0	124	8.4	.02	1+
5.5	362	24.5	.05	1+ 2+
6.0	348	23.5	.07	2+
6.5	260	17.6	.08	2+
7.0	160	10.8	.11	2+ 3+
7.5	91	6.2	.14	3+
8.0	49	3.3	.17	4+
8.5	22	1.5	.20	4+
9.0	18	1.2	.24	4+ 5+
9.5	11	0.7	.26	*
10.0	8	0.5	.33	
10.5	13	0.9	.40	
11.0	1	0.1	.45	
11.5	3	0.2	.48	
12.0	2	0.1	.55	
13.0	3	0.2	.75	
TOTAL	1,479			

*Gizzard shad from 9.5 to 13 inches long were not aged.

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF BLUEGILL

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
1.5	5	0.8	Trace	0+
2.0	1	0.2	Trace	0+
2.5	3	0.5	.02	0+
3.0	3	0.5	.02	1+
3.5	17	2.8	.02	1+
4.0	43	7.1	.04	1+ 2+
4.5	103	17.1	.05	3+
5.0	128	21.2	.06	3+ 4+
5.5	145	24.0	.09	4+
6.0	125	20.7	.12	4+ 5+
6.5	25	4.1	.17	5+ 6+
7.0	5	0.8	.21	6+
TOTAL	604			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF WHITE CRAPPIE

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
4.5	1	0.4	.04	0+
5.0	89	35.7	.03	1+
5.5	37	14.9	.05	1+ 2+
6.0	66	26.5	.06	2+
6.5	28	11.2	.08	2+
7.0	9	3.6	.09	2+ 3+
7.5	5	2.0	.11	4+
8.0	4	1.6	.21	4+
8.5	1	0.4	.23	4+
9.0	3	1.2	.33	5+
10.0	2	0.8	.51	6+
10.5	2	0.8	.58	6+
11.5	2	0.8	.82	6+
TOTAL	249			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF GOLDEN REDHORSE

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
3.0	1	0.5	Trace	Not aged
6.5	1	0.5	.09	
8.5	1	0.5	.24	
10.0	2	1.0	.41	
10.5	1	0.5	.59	
11.0	1	0.5	.55	
11.5	11	5.6	.60	
12.0	13	6.6	.71	
12.5	13	6.6	.79	
13.0	28	14.1	.83	
13.5	26	13.1	.90	
14.0	26	13.1	1.01	
14.5	24	12.1	1.11	
15.0	20	10.1	1.22	
15.5	15	7.6	1.41	
16.0	8	4.0	1.55	
16.5	1	0.5	1.65	
17.0	3	1.5	2.10	
17.5	2	1.0	2.31	
18.0	1	0.5	1.81	
TOTAL	198			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF LARGEMOUTH BASS

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
3.0	10	6.5	.02	0+
3.5	9	5.8	.02	0+
4.0	10	6.5	.03	0+ 1+
4.5	5	3.2	.04	1+
5.0	5	3.2	.04	1+
5.5	7	4.5	.07	1+
6.0	5	3.2	.08	2+
6.5	3	1.9	.12	1+
7.0	3	1.9	.15	2+
7.5	4	2.6	.18	2+
8.0	4	2.6	.23	2+
8.5	5	3.2	.28	2+ 3+
9.0	12	7.8	.31	3+
9.5	5	3.2	.41	3+
10.0	5	3.2	.44	3+
10.5	5	3.2	.62	4+
11.0	10	6.5	.63	4+
11.5	5	3.2	.76	4+
12.0	1	0.6	1.05	4+
12.5	5	3.2	1.09	4+
13.0	3	1.9	1.23	4+
13.5	2	1.3	1.17	4+
14.0	5	3.2	1.57	5+
14.5	4	2.6	1.59	5+

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF LARGEMOUTH BASS (cont.)

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
15.0	4	2.6	2.01	5+
15.5	2	1.3	2.01	5+
16.0	1	0.6	2.30	5+
16.5	2	1.3	2.74	5+
17.0	4	2.6	2.82	5+
17.5	3	1.9	2.97	5+
18.0	2	1.3	2.97	6+
18.5	3	1.9	3.63	6+
19.0	1	0.6	3.60	6+
TOTAL	154			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF YELLOW BASS

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
3.5	1	1.1	.01	0+
4.0	1	1.1	.03	0+
5.5	15	16.5	.07	1+
6.0	54	59.3	.08	1+
6.5	5	5.5	.10	1+
7.0	6	6.6	.12	1+
7.5	5	5.5	.17	2+
8.0	2	2.2	.17	2+
9.5	1	1.1	.35	4+
10.5	1	1.1	.52	5+
TOTAL	91			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF CHANNEL CATFISH

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
7.5	3	4.6	.11	Not aged
8.0	2	3.1	.09	
8.5	2	3.1	.11	
9.0	3	4.6	.17	
9.5	3	4.6	.23	
10.0	3	4.6	.24	
10.5	4	6.2	.32	
11.0	7	10.8	.28	
11.5	7	10.8	.39	
12.0	6	9.2	.40	
12.5	2	3.1	.47	
13.0	5	7.7	.54	
13.5	2	3.1	.64	
14.0	1	1.5	.95	
15.0	1	1.5	.93	
15.5	1	1.5	1.37	
16.0	1	1.5	1.35	
17.5	3	4.6	1.71	
19.0	1	1.5	2.27	
19.5	2	3.1	2.73	
20.0	2	3.1	2.99	

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF CHANNEL CATFISH (cont.)

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
20.5	1	1.5	3.45	Not aged
21.5	1	1.5	4.50	
24.5	1	1.5	4.70	
26.0	1	1.5	7.70	
TOTAL	65			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF REDEAR SUNFISH

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
6.0	8	17.4	.12	4+ 5+
6.5	29	63.0	.14	5+
7.0	8	17.4	.19	5+
7.5	1	2.2	.23	6+
TOTAL	46			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF SPOTTED BASS

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
3.0	5	14.7	.01	1+
3.5	5	14.7	.02	1+
4.0	3	8.8	.02	1+
5.5	3	8.8	.06	2+
6.0	1	2.9	.07	2+
8.0	3	8.8	.25	3+
9.0	4	11.8	.32	3+
9.5	1	2.9	.39	4+
11.0	7	20.6	.73	4+
11.5	1	2.9	.76	4+
13.5	1	2.9	1.09	4+
TOTAL	34			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF CARP

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
16.0	2	6.1	2.17	Not aged
16.5	2	6.1	2.18	
17.0	1	3.0	2.54	
17.5	3	9.1	2.72	
18.0	1	3.0	2.67	
18.5	3	9.1	3.14	
19.0	1	3.0	3.14	
19.5	2	6.1	3.23	
20.0	1	3.0	3.84	
20.5	2	6.1	4.51	
21.0	2	6.1	4.32	
21.5	3	9.1	5.07	
22.0	1	3.0	4.93	
22.5	2	6.1	5.95	
23.0	3	9.1	5.44	
23.5	2	6.1	6.27	
25.0	1	3.0	4.50	
27.5	1	3.0	10.10	
TOTAL	33			

21. NUMBER, PERCENTAGE, WEIGHT, AND AGE OF YELLOW PERCH

TOTAL LENGTH (inches)	NUMBER	PERCENTAGE	AVE.WEIGHT (pounds)	AGE
5.0	4	14.3	.03	1+
5.5	6	21.4	.04	1+ 2+
6.0	12	42.8	.06	2+
6.5	6	21.4	.07	2+ 3+
TOTAL	28			

6.

Species	Year Class	Number	I	II	III	IV	V	VI
					Back Calculated Length			
Gizzard shad	1981	11	3.7					
	1980	27	4.2	5.4				
	1979	17	4.3	5.5	6.4			
	1978	9	4.3	5.3	6.2	7.1		
	1977	14	3.7	5.0	6.1	7.1	7.9	
	Weighted	Average	4.1	5.3	6.3	7.1	7.9	
		(Number)	(78)	(67)	(40)	(23)	(14)	( )
Species								
Bluegill	1981	15	1.4					
	1980	7	1.4	2.7				
	1979	17	1.5	2.7	3.8			
	1978	14	1.3	2.3	3.8	4.7		
	1977	10	1.2	2.4	3.5	4.5	5.3	
	1976	8	1.3	2.6	3.7	4.6	5.4	6.0
	Weighted	Average	1.3	2.5	3.7	4.6	5.3	6.0
		(Number)	(71)	(56)	(49)	(32)	(18)	(8)
Species								
White crappie	1981	18	2.8					
	1980	22	2.9	5.0				
	1979	5	3.1	4.7	5.8			
	1978	8	3.2	4.7	5.9	7.0		
	1977	3	2.5	4.3	5.7	6.9	7.9	
	1976	4	2.6	4.4	5.8	7.1	8.2	9.2
	Weighted	Average	2.9	4.8	5.8	7.0	8.1	9.2
		(Number)	(60)	(42)	(20)	(15)	(7)	(4)
Species								
Largemouth bass	1981	17	3.0					
	1980	16	3.0	5.5				
	1979	17	3.1	5.3	7.3			
	1978	25	3.4	5.7	7.7	9.6		
	1977	23	3.7	6.2	8.3	10.9	13.5	
	1976	5	3.6	7.0	9.3	11.7	14.1	16.[illegible]
	Weighted	Average	3.3	5.8	7.9	10.4	13.6	16.[illegible]
		(Number)	(103)	(86)	(70)	(53)	(28)	([illegible])

Species	Year Class	Number	Back Calculated Length I	II	III	IV	V	VI
Yellow bass	1981	24	4.0					
	1980	6	4.2	6.9				
	*1978	1	3.6	6.0	7.7	8.6		
	*1977	1	3.4	6.0	7.4	8.8	9.7	
	Weighted Average (Number)		4.0 (30)	6.9 (6)	( )	( )	( )	( )
Redear sunfish	1978	3	2.0	3.9	5.1	5.8		
	1977	15	2.0	3.5	4.4	5.2	5.9	
	*1976	1	2.6	3.6	4.7	5.6	6.1	
	Weighted Average (Number)		2.0 (18)	3.6 (18)	4.7 (18)	5.6 (18)	5.9 (15)	( )
Spotted bass	1981	7	2.3					
	1980	3	2.5	4.5				
	1979	4	2.7	5.0	6.9			
	1978	7	2.7	4.9	6.6	9.1		
	Weighted Average (Number)		2.5 (21)	4.8 (14)	6.7 (11)	9.1 (7)	( )	( )
Yellow perch	1981	5	4.0					
	1980	13	3.2	4.8				
	1979	4	3.4	4.7	5.5			
	Weighted Average (Number)		3.4 (22)	4.8 (17)	5.5 (4)	( )	( )	( )

*Sample less than three not included in averages.

23. FALL SAMPLE None taken

SPECIES	NUMBER	SIZE RANGE (INCHES)

24. FISH PARASITES AND DISEASES None observed

25. EVIDENCE OF EROSION OR POLLUTION Much sediment deposition in eastern basin

26. OTHER SPECIES COLLECTED

NO.	SPECIES	LENGTH RANGE (INCHES)	WEIGHT RANGE (POUNDS)
14	Golden shiner	5.6 - 8.2	0.06 - 0.23
14	Logperch	3.9 - 6.0	0.02 - 0.09
13	Warmouth	2.6 - 7.5	0.01 - 0.33
10	Flathead catfish	5.7 -19.0	0.05 - 2.52
7	Brook silverside	2.7 - 4.3	0.01 - 0.02
3	Spotted sucker	15.0 -17.0	1.39 - 2.00
3	Spotfin Shiner	2.7 - 3.3	Trace
3	White sucker	13.6 -13.7	1.01 - 1.04
1	Yellow bullhead	9.2	0.35

FISH MANAGEMENT PROJECT

LAKE Lemon

COUNTY Monroe

BIOLOGIST Steve Andrews

FISH ERADICATION

A. RECOMMENDED MANAGEMENT: SELECTIVE ______ PARTIAL ______ TOTAL ______ DRAINAGE ______

B. PISCICIDE: ANTIMYCIN ______ ROTENONE ______

C. CONCENTRATION: ______ (ppm) (ppb) ______ GAL. OR ML./ACRE-FOOT

D. ACRE-FEET TO BE TREATED: ______

E. AMOUNT OF CHEMICAL: ______

F. CHEMICAL COST: ______

G. ESTIMATED DATE OF PROJECT: ______

FISH STOCKING

A. TYPE: NEW INTRODUCTION X SUPPLEMENTAL ______ NEW HABITAT ______

B.

SPECIES	NUMBER	SIZE	DATE
White bass	5-700	adult	Spring 1984

GEH:EH
SEPT. 1975

APPENDIX D

EXAMPLES OF PUBLIC INFORMATIONAL BROCHURES ON LAKE MANAGEMENT

How to Control Milfoil

Metro has prepared this fact sheet to provide detailed information about milfoil control —technical aspects, cost estimates, people who provide milfoil control services and advice on composting milfoil after it's removed from the water.

Is milfoil a problem for you?

Eurasian watermilfoil is an aquatic plant that has become a nuisance in King County waters since the early 1970s. In overabundance, milfoil interferes with wildlife and the recreational use of our lakes.

For the last three years Metro has taken the lead in coordinating efforts to control milfoil in Seattle and King County public waters and providing information about ways citizens can control milfoil around their docks and beaches.

The Metro Council adopted a comprehensive policy that recommends the use of non-chemical methods for milfoil control. The policy specifically advises against using certain chemical herbicides. More specific information follows.

Non-chemical ways lake users or property owners can control milfoil include hand-pulling, bottom-screening and mechanical harvesting.

Hand-pulling

Hand-pulling is a simple way to control milfoil, especially around docks and swimming areas. The plant may need to be pulled more than once each summer to keep an area clear.

If it is inconvenient for you to "weed," local people looking for summer employment are willing to hand-pull for hire. Metro urges you to consider hiring local neighborhood youth. The following people have expressed interest in providing hand-pulling services:

BPD Weed Control	523-5735	Seattle Eastside
Mark and Scott Cairns	885-4447	Lake Sammamish
The Compleat Service, Inc.	455-3744	Eastside
Jim Duran	232-8713	Mercer Island
David Grayston	522-4647	Seattle
Dan Grosse	543-7367	Seattle
William Schuck	938-2716	Seattle
David Sherman	232-7012	Mercer Island

Figure C-1. Milfoil control brochure developed for the City of Seattle, Washington.

Bottom Screening

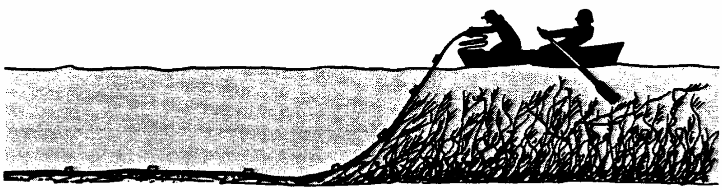
Bottom-screening can control milfoil in swimming beaches, around docks and in other small areas. One product, a woven, fiberglass fabric, restricts light and space for plant growth. Burlap and perforated black mylar may produce similar results.

Local bottom screen distributors:

Allied Aquatics
Doug Dorling
6001 A McKinley Avenue
Tacoma, WA 98404
Phone — 475-1207

Beals Aquatics
5404 Steilacoom Blvd. S.W.
Tacoma, WA 98499
Phone — 584-1222, 475-3749

Vern Shultz, Poseidon Pioneers
127 Sixth Avenue
Kirkland, WA 98033
Phone — 822-5344



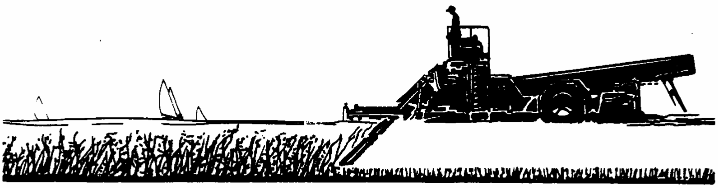
Mechanical harvesting

Floating harvesters are available to cut aquatic plants below the water surface and collect the cut plant material for removal. Because harvesting machines require maneuvering space, they generally cannot be used around docks or piers. Machine harvesting works best in large, open areas where several neighbors may cooperate for aquatic weed control. They are ideal for small lakes and for lily pad control.

Contact:

Washington Environmental Council
107 S. Main
Seattle, WA 98104
Phone — 623-1483

Figure C-1 continued.



Chemical control

Research indicates that herbicides may pose a risk to human health, wildlife and water quality. Metro policy advises against using dichlobenil—or Casoron—diquat and 2,4-D. It suggests using the herbicide endothall only if non-chemical milfoil control is not feasible. State law requires that aquatic herbicides be applied only by licensed applicators.

Some government agencies are interested in the impact certain milfoil control methods may have on the environment. They review proposed activities and issue permits. Harvesting and hand-pulling generally do not require permits. For additional information about permits or milfoil control, contact your local shoreline management office or call Metro at 447-5883.

Licensed applicators:

Allied Aquatics
6001 A McKinley Avenue
Tacoma, WA 98404
Phone — 475-1207

Aquatic Control
19104 29th Avenue East
Tacoma, WA 98445
Phone — 847-6058

Now that I've got it, what can I do with it?

Milfoil makes an excellent mulch or compost.

Mulch. Because of its high nutrient content, milfoil improves soil. For use in garden plots, either use it as a mulch or till it directly into soil. For best results, let the milfoil drain for three or four days.

Compost. A milfoil compost for your garden takes just two weeks to make if you follow these steps:

- Dry harvested milfoil on a drying rack, wooden pallet or other elevated area for about 24 hours. That reduces the moisture content and makes the milfoil easier to handle.
- Construct a 3' x 3' compost bin or layer material directly on the ground.
- Using a 5-gallon plastic bucket or other measure, layer material in this order: 5 parts fresh green grass or other green material; 2 parts milfoil; 2 parts vegetable scraps, if available; 4 parts brown grass, dry leaves or other dry matter broken up by a hand mower.
- Stack compost layers about 3 ft. high. Cover the pile with plastic to protect it from rain.
- In 4 or 5 days, turn the pile under and add more grass clippings. Turn the pile under once again one week later before using as compost.

Figure C-1 continued.

Cost Comparison of Milfoil Control Methods

Method	Large Areas (per acre costs)*	Average Waterfront Lot (Apx. 60' · 70')*	Notes
Hand-pulling	Not recommended	Varies from no cost to $100 and up	Costs vary from $120 to $300 per lot depending on labor and expertise: or homeowner may perform task. No permits required.
Mechanical Harvesting	$250 per day	$250 per day (for several lots)	Total cost depends on weed density and underwater obstructions. Can cut about one acre per day.
Bottom screen (maximum 2,000 sq. ft.)	Not recommended	$600 first year, $120 thereafter.	Not suitable for large-scale application but is the best long-term solution. Bottom screen is designed for recreation areas such as beaches or around docks. Bottom screen costs include screen purchase and installation the first year and annual maintenance. Maximum 2,000 square foot coverage recommended due to permit requirements and retention of fish habitat.
Endothall	$555	$300-400	Aquatic herbicide must be applied by licensed applicators. Carry-over effect to subsequent years may be minimal. Permits are required. Contact your local jurisdiction planning department for more information.

*Approximate costs — call vendors for site specific estimates.

For more information about milfoil control call Metro's Comprehensive Water Quality Division, 447-5883.

METRO
Municipality of Metropolitan Seattle
821 2nd Ave.
Seattle, Wa. 98104

July 1982

Figure C-1 continued.

Hand-harvesting Eurasian Water-milfoil provides effective seasonal control without:

- *affecting water chemistry*
- *causing significant disruption of the lake bottom*
- *interfering with the natural aquatic ecology*
- *posing any threat to public health*

Published by Municipality of Metropolitan Seattle

METRO

Taking the Problems of Aquatic Weeds Into Our Own Hands

Tips on:

Hand-Harvesting Eurasian Watermilfoil

AND OTHER NUISANCE AQUATIC PLANTS

PREPARED BY GREENPEACE

Figure C-2. Six-panel weed pulling brochure developed for the City of Seattle, Washington.

Figure C-2 continued.

The Problem

Eurasian watermilfoil is an aquatic plant that has become a nuisance in many bodies of water in the Pacific Northwest and elsewhere. Unlike algae, milfoil has a root system and grows only where sunlight penetrates to the bottom of the lake or waterway tapering off at depths of around fifteen feet. The plant is not native to this continent. After introduction to a body of water, milfoil can reproduce rapidly and tends to disrupt the normal ecological balance and mix of plant life. At the height of the growing season, when sunlight is strongest, milfoil's spaghetti-like stem and spidery green filaments reach the water surface and will persist until autumn. Though fish and other aquatic life forms are not greatly affected the dense and unsightly growth can impede certain recreational uses of the water.

Eurasian watermilfoil

The Method

The manual control techniques outlined here provide a number of methods individuals can use to remove milfoil themselves. Like weeding a garden or lawn, hand-pulling milfoil results in satisfactory control of potential infestation. It should be understood that no method has been developed that can totally eliminate the plant. Though it is possible to get some of the root system when pulling the plant, merely cutting it off near the roots after the crown of the plant has reached the surface significantly retards growth for most or all of the growing season.

Preparation

To date, no permits have been required for hand-harvesting milfoil. If any activity stands to have significant impact on the aquatic environment local and state authorities should be consulted in advance.

Since milfoil reproduces by fragmentation, harvesters should use netting to section off a work area if a current fast enough to carry off floating material exists. People preparing to wade along an unfamiliar shoreline should wear something to protect their feet. Swimmers and boaters should follow standard safety procedures. Work in pairs and be aware of possible fatigue. Have first-aid supplies on hand.

4 Steps to Getting the Job Done:

1. Cutting or Pulling: The simplest way to harvest milfoil involves simply pulling or cutting the plant near the roots. This can be done by wading, from boats, or from dockside. When a large part of the infested area is in depths over a person's head, it is best to plan on diving. One alternative to diving is to use rakes as tools to entangle and pull up the plants. It is often preferable to cut the plants. This leaves the root system intact but avoids stirring up silt from the lake bottom. Knives or sharp instruments need not be used. Milfoil can be cut using a 3 foot long ½ inch fiberglass rod by sweeping the rod back and forth along the lake bottom. When diving, it is not necessary to gather the milfoil as the cut plant will float to the surface. Scuba gear can be helpful, however, a strong swimmer can work without air tanks using only flippers and a face mask.

2. Skimming: After milfoil has been cut it is important to gather all floating fragments. For a large operation the "seine" net method (described below) is best. A satisfactory job can be done with hand-held fishing nets or nets used for cleaning pools.

3. Draining: As milfoil retains a very high quantity of water after harvesting, it is advisable to allow the plant matter to drain. If the harvested milfoil is spread out in the sun it dries quickly with minimal odor.

4. Composting: Whenever possible, milfoil should be turned into soil. The plant contains significant quantities of nitrogen, phosphorus, and calcium and makes good compost. After draining it is light and easy to transport.

Appropriate Technology

Innertube and Net: An inflated 16-inch truck tire innertube with fish net secured by netting twine can be towed alongside a boat or swimmer. This proves to be a convenient place to load harvested milfoil as it floats in the water and will allow the milfoil to drain when dragged on shore.

"Seine" Net Skimmer: A length of fish net of four feet in depth can be used to collect detached plants from the water surface. Floats should be attached to the top of the net and weights to the bottom. The net can then be pulled between two swimmers or boats.

Photography by Jeff Miller and Bruce Hoeft — Layout by Work Shop Printers

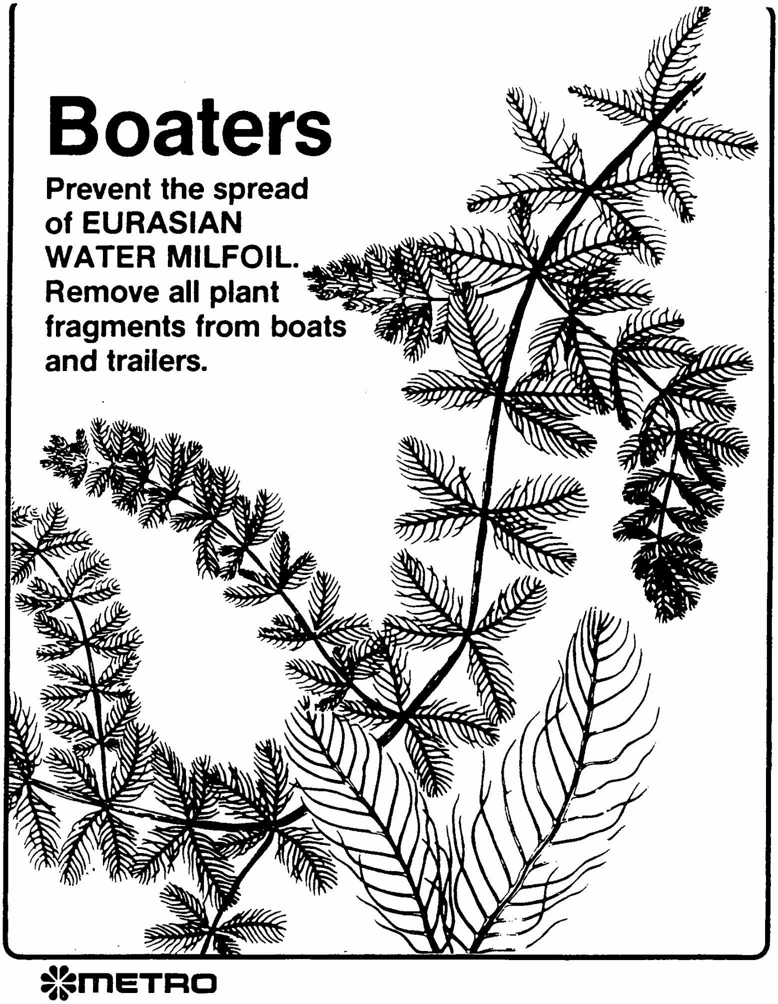


Figure C-3. Example of a sign posted at Lake Washington boat launch ramps warning boaters to help prevent the spread of Milfoil to other lakes.

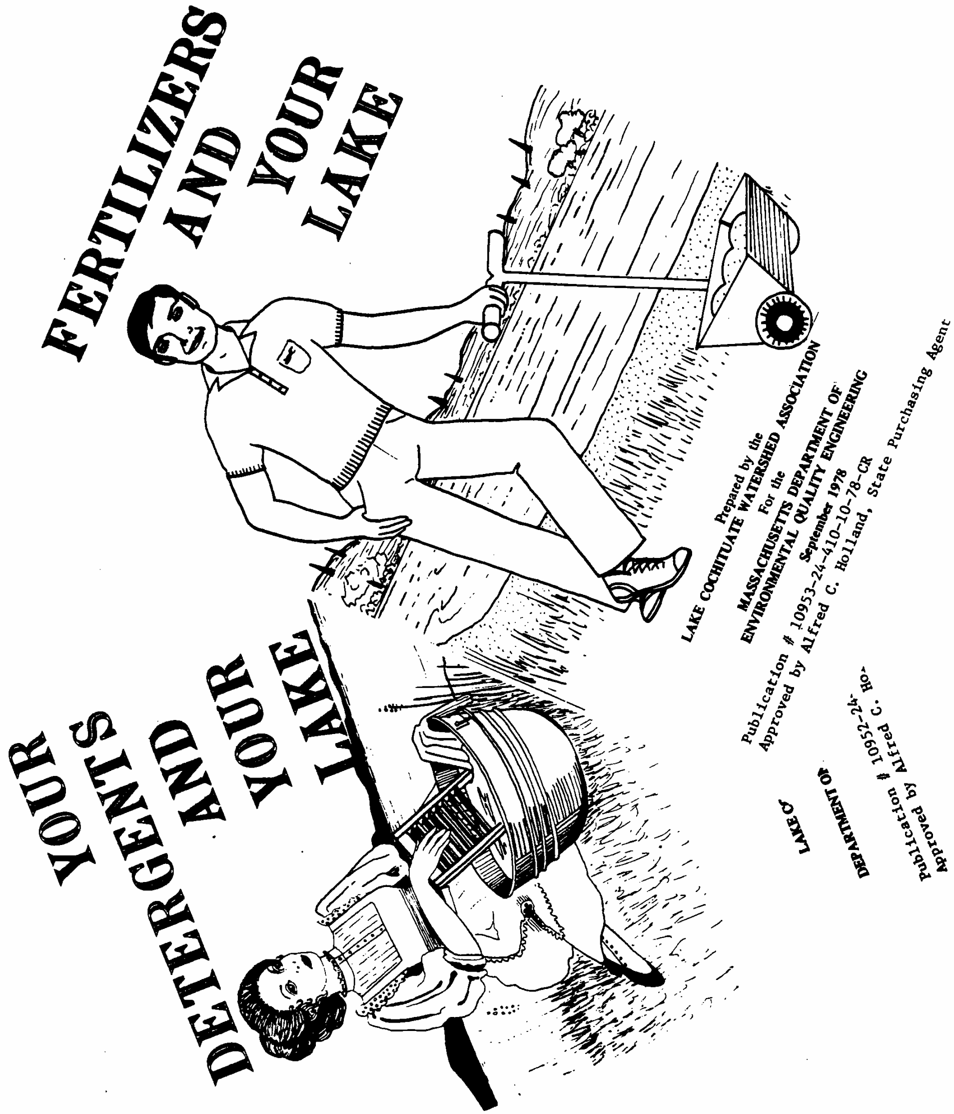


Figure C-4. Brochures to educate lakeshore homeowners about reducing nutrient inputs to lakes.

APPENDIX E

CLEAN LAKES PROGRAM REGULATIONS

federal register

Tuesday
February 5, 1980
Vol. 45, No. 25, page 7788

Final Rule

Environmental Protection Agency

COOPERATIVE AGREEMENTS FOR PROTECTING AND RESTORING PUBLICLY OWNED FRESHWATER LAKES

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 35

[FRL 1388-4]

Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: This regulation establishes policies and procedures by which States may enter into cooperative agreements to assist in carrying out approved methods and procedures for restoring publicly owned freshwater lakes, and protecting them against degradation, as authorized by section 314 of the Clean Water Act (33 U.S.C. 1251 *et seq.*). This regulation was proposed on January 29, 1979 (44 FR 5685) for a sixty-day public comment period. EPA received 48 letters of comment which we have considered in developing this regulation.

EFFECTIVE DATE: This regulation governs only clean lakes cooperative agreements which are awarded after February 5, 1980. Cooperative agreements and grants that are awarded before February 5, 1980, will continue according to their original terms subject to the regulations under which the funds were awarded. Clean lakes applications received before February 5, 1980 will be processed according to past procedures.

ADDRESSES: Comments submitted on these regulations may be inspected at the Public Information Reference Unit, EPA Headquarters, Room 2922, Waterside Mall, 401 M Street, SW., Washington, D.C. 20460, between 8 a.m. and 4 p.m. on business days.

FOR FURTHER INFORMATION CONTACT: Joseph A. Krivak, Criteria and Standards Division (WH-585), Environmental Protection Agency, Washington, D.C. 20460. Telephone: (202) 755-0100.

SUPPLEMENTARY INFORMATION: This regulation contains the policies and procedures governing the provision of Federal financial assistance to States for the protection and restoration of publicly owned freshwater lakes as authorized by the Clean Water Act (33 U.S.C. 1251 *et seq.*) Section 314. The program is called the clean lakes program.

The Federal Grant and Cooperative Agreement Act requires all Federal Agencies to classify each assistance transaction as either a grant or a cooperative agreement. EPA will award grants when little Federal involvement in the project is expected, and cooperative agreements when significant Federal involvement is anticipated. We expect significant EPA involvement in all Clean Lakes projects and have designated cooperative agreements as the appropriate award instrument.

Section 314 requires each State to prepare and submit a report to EPA including: (1) An identification and classification of all publicly owned freshwater lakes in that State according to eutrophic condition; (2) procedures, processes, and methods (including land use requirements) to control sources of pollution of these lakes; and (3) methods and procedures, in conjunction with appropriate Federal agencies, to restore the quality of these lakes. Section 314 also provides financial assistance to States to implement lake restoration and protection methods and procedures approved by the Administrator.

Pub. L. 95-217, amended section 314(b) of the Clean Water Act by adding the following: "The Administrator shall provide financial assistance to States to prepare the identification and classification surveys required in subsection (a)(1) of this section." On July 10, 1978, EPA published a notice of availability in the Federal Register for States to: identify and classify their publicly owned freshwater lakes according to trophic condition, establish priority rankings for lakes in need of restoration; and conduct diagnostic-feasibility studies to determine methods and procedures to protect or restore the quality of those lakes (43 FR 29617). Total assistance of up to $100,000 is available to each State for this lake classification survey. No award can exceed 70 percent of the eligible cost of the proposed project.

EPA carefully evaluated the performance of the clean lakes program during 1977 to determine how it might be improved. Based on this evaluation, we developed the revised procedures contained in this regulation. We published the proposed section 314 regulation, in the Federal Register (44 FR 5685) on January 29, 1979, for a sixty-day public comment period. In addition, we sent approximately 1000 copies of the proposed rule to the people identified on the current mailing list of the Environmental Resources Unit of the University of Wisconsin—Extension, to State agencies, environmental interest groups and specific requestors. The official comment period closed on March 30, 1979, and EPA has received 48 comment letters.

The following discussion responds to the comments received on the proposed regulation and is arranged in the order of the sections of the regulation. Changes made in the final form of the regulation in response to public comment are discussed. Our responses to significant comments that did not lead to changes are also discussed.

Definitions

Freshwater lake

Some commenters believed that the definition of freshwater lake (§ 35.1605-2) should not include a limiting value for total dissolved solids (TDS). Section 314 allows funding only for publicly owned "freshwater" lakes. Since TDS is found in various scientific texts as a measure to distinguish freshwater from brackish water and saltwater, we believe it is relevant. We have selected a value of 1 percent TDS which is ten times the value used on page 306 in the *Water Encyclopedia*, Water Information Center, Inc., Port Washington, New York, 1970. We used the high value so that freshwater lakes that have received a high TDS loading a result of irrigation return flows and other land management practices (primarily in the far West) can be eligible.

Publicly owned freshwater lake

Several comments concerned the definition of "publicly owned freshwater lake" (§ 35.1605-3). We proposed that a publicly owned freshwater lake is, "[a] freshwater lake that offers public access to the lake through publicly owned contiguous lands so that any member of the public may have the same or equivalent opportunity to enjoy privileges and benefits of the lake as any other member of the public or as any resident around the lake." We understand that a lakeshore property owner stands to receive greater benefit from a lake than a day visitor. We have omitted reference to the lakeside resident, but we are still concerned about the potential for the clean lakes program providing benefits to the lakeshore property owner rather than the general public. However, since projects demonstrating the greatest public benefits will receive the highest priority under the review criteria in § 35.1640-1, we do not expect problems.

Other commenters questioned the appropriateness of requiring publicly owned contiguous land as the public access point. We believe the requirement is necessary to ensure that the public maintains unrestricted use of a lake after it is improved. Even so, in some cases where publicly owned contiguous land is not available, the lake may have substantial public use and benefit. One State indicated that by State statute all lakes greater than 10 acres surface area are in the public domain even if the shoreline is totally private. The State statute also guarantees that public access will be provided. In these cases EPA will require the State to define exactly where the public access points are, and to provide written agreements between the State and particular private property owners specifying the conditions and limitations of the public access. We will also require permanent signs to show the public access points and specify any lake use limitations. Similarly, States could negotiate long terms leases or similar arrangements with private land owners, including private non-profits groups, to provide the necessary public access points. Again, we will require signs to indicate the limitations and extent of the public access. These arrangements would have to be completed before the award.

Eligibility

Some commenters suggested that section 314 cooperative agreements should continue to be awarded to local agencies. They contend that, otherwise, there will be a substantial erosion of the grassroots orientation of the program. We support the need to keep a grassroots thrust in the clean lakes program because of the voluntary nature of this assistance program. However, section 314 permits award of assistance only to States. Even so, since some States may not provide all the matching support required in clean lakes cooperative agreements, local agencies may provide the required remaining matching funds. We believe this funding partnership will preserve the grassroots nature of the program. We will work with the appropriate State agencies to assure that they minimize associated paperwork and "redtape," and provide clear concise guidance to local agencies. This will help to maintain the enthusiasm and involvement of local agencies.

EPA received several comments concerning the eligibility of Indian Tribes for section 314 funding. The commenters were concerned that, because Indian lands do not fall under the dominion of State Government, Tribal Governments may not be able to participate in this program. The statutory requirements of section 314 restricts award of assistance only to States. Section 35.1615 allows States to make financial arrangements with agencies located within the State including Indian Tribes to support lake restoration projects.

Some commenters objected to EPA's policy of not awarding assistance for lakes that are used only as drinking water supplies. EPA has operated under this policy since the first awards under the clean lakes program in January 1976. We believe that the primary purpose of section 314 is to implement the goals of the Clean Water Act stated in section 101(a) as they relate to publicly owned freshwater lakes. Section 101(a)(2) states that, "* * * it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for *recreation* in and on the water be achieved by July 1, 1983." (emphasis added) The conference committee report of the 95th Congress, first session (House Report No. 95-830) made special note on page 94 in the comments of changes made to the Clean Water Act by the 1977 Amendments, that EPA should give special attention to restoring lakes which offer the potential for high utility as recreation areas. In keeping with the existing EPA policy and in support of the Congressional intent, we do not believe it is appropriate to allow funding of projects for lakes that are used only as drinking water supplies. Other funding sources are available to assist municipalities and States with protecting or improving drinking water supplies. Most communities accomplish this by assessing an appropriate water users fee under a regular billing procedure to support reservior and processing plant operation and maintenance costs. Also, a portion of city and county taxes is likely to be used for such high priority community expenses.

Funding Levels

In the preamble of the proposed regulation, we requested comments on the proposed phasing of clean lakes cooperative agreements and the funding levels designated for each. The seventeen commenters who responded did not present persuasive arguments that the program would be more effective if the proposed matching requirements were reduced.

We continue to believe that the 50 percent matching requirement requires sufficient State/substate (non-Federal) commitment to assure the best project is implemented and proper maintenance of the project is continued after implementation is complete.

Lake Classification Requirement

A number of the comments concerned § 35.1630 requiring States to classify their publicly owned freshwater lakes in need of protection and restoration by January 1, 1982 in order to be eligible for funding support after that date under section 314. As explained in the preamble of the proposed rule, this requirement does not mean that all of a State's publicly owned freshwater lakes must be surveyed, but a State must provide EPA with survey results of their priority lakes and the rationale for selecting the lakes surveyed. Other comments concerned EPA financial assistance to the States to perform the lake classification requirement. EPA will continue to award this cooperative agreement to States on a one-time-basis, under the July 10, 1978, Federal Register notice, until September 30, 1981. Approximately 20 States applied for this funding assistance. Most projects will be conducted over 18 months. We will restrict funding of this activity to a one-time award until all States electing to participate have initiated these efforts, and we have reviewed the overall program results.

Monitoring

A few commenters suggested the EPA should make available a third award phase for intensive monitoring of perhaps 10 percent of the implementation projects. The projects would be carefully selected to evaluate those lake restorative techniques that have little documentation on their capabilities and effectiveness. Although committed to strengthen the understanding of procedures to protect and restore the quality of the Nation's lakes, we continue to believe that some monitoring of each project during and after project implementation will provide us with a better review of program effectiveness than intensive monitoring in a few projects. However, we are encouraging EPA's Office of Research and Development to conduct a greater number of intensive investigations of lake protection and restoration techniques under the 104(h) authority of the Clean Water Act. We believe this approach will be responsive to both the program needs and the intent of the legislation.

Application and Priority

Several commenters asked how many Phase 1 and Phase 2 project applications an individual State could submit for funding consideration. The regulation does not specify a number. However, all applications must receive a State priority and we will consider the State priority placed on an application along with the other criteria presented in § 35.1640-1 when developing funding recommendations. We do foresee instances where, after considering all of these factors, a State may receive more than one of each type of cooperative agreement.

A significant number of comments where received on the required content of Phase 1 project applications. Most of these comments indicated that the information required is excessive and costly to assemble or obtain. As discussed in the preamble of the proposed rule, we believe that this information should be readily available to States and local agencies. No study or water quality monitoring is necessary to obtain the information since only the presentation of existing information is required. Furthermore, the information required in Phase 1 applications is precisely the information that participating States are required to assemble under their lake classification surveys conducted under the July 10, 1978, Federal Register notice.

We have reduced the mandatory information required in Phase 1 applications in response to those comments. Although not mandatory, § 35.1620-2(b) still includes a list of information that EPA believes should be in a Phase 1 application to allow EPA to effectively evaluate project applications and make funding decisions. Applications describing a proposed project in more complete terms may receive higher rating when evaluated according to the review criteria in § 35.1640-1.

EPA received four comments on the State requirement to set priorities on Phase 1 and Phase 2 projects as stated in § 35.1620-5. The commenters were concerned principally with the State capability to foresee specific projects 12 to 18 months in advance in sufficient detail to allow them to apply realistic funding priorities. We understand the problems associated with these procedures and realized that projects and associated priorities set more than a year in advance are subject to change. In § 35.1620-5 we have allowed States to alter project priority lists with a minimum of State effort. We need the information contained on State priority lists to determine program needs. We also need it to provide a basis for adjusting our workforce to match the identified workload.

Allotment

In the preamble of the proposed regulation we request comments regarding the allocation of clean lakes program appropriations to assure an equitable distribution of funds among the States. We received 6 comments on this issue; 4 supporting the status quo, one supporting the specification in the regulation of an annual deadline for application submission, and the other suggesting that an allocation of appropriations be made directly to the

States, although no formula was proposed. EPA's Office of General Counsel (OGC) and Grants Administration Division (GAD) suggested that a Regional allocation formula be considered as a means of providing equitable funding distribution. Despite the relatively small amount of program appropriations, we believe an allocation procedure has considerable merit. The advantages include: Regional flexibility in the negotiations with States for lake restoration projects, and better Regional capability to forecast workloads and develop appropriate manpower plans for annual budget submissions. Considering the advantages mentioned above, EPA will provide each Regional office a resource target from the section 314 appropriation based on State's identification of clean lakes work in the State WQM work programs. The State identification will consist of a two year forecasting of clean lakes applications, with funding needs, as part of the annual work program. The summation of these forecasts, coupled with the Congressional appropriation, will permit EPA to provide equitable resource targets. Regional offices will use these targets to negotiate projects within each State.

Targetting, based upon two year forecasting in work programs, will take effect in fiscal year 1982. For fiscal year 1981, EPA will target resources based on State-supplied information in existing State/EPA agreements, WQM work programs, and from the WQM Needs Survey.

Review Criteria

We have changed the application review criteria presented under § 35.1640-1 to reflect several comments. We have added a criterion to emphasize the importance of improving fish and wildlife habitat, and improving the populations of fish species.

A few commenters questioned the applicability of application review criteria § 35.1640-1(a)(4)(ii-iv). We believe that these criteria should be considered by States to judge the cost of a project in relation to public benefits derived, e.g., the more persons using a restored or protected lake the greater the benefits from the expenditure of public funds. Further, persons with low incomes cannot travel easily to lakes for recreational purposes unless the lakes are close to have sufficient public transportation to them. Such factors should be considered in the decision making process. This component is not intended to preclude lakes in rural settings from receiving financial assistance under the clean lakes program.

The project award procedures under § 35.1650 have been changed. All EPA funding decisions will be made in the EPA Regional office by officials designated by the Regional Administrator. Program guidance and technical assistance will be supplied by EPA Headquarters, and all project applications will receive Headquarters review and technical recommendations.

Limitations on Award

Most comments on § 35.1650-2 were editorial and only minor changes in the language of this section have been made. Specific comments questioned the exclusion of aquatic plant harvesting as a lake restoration procedure. Section 35.1650-2(b)(5) does not exclude aquatic plant harvesting from supportable lake restoration programs. However, we believe that aquatic plant harvesting is only a temporary restorative measure in cases where pollution control measures are not implemented in the watershed to the greatest practicable extent. Even in cases where such pollution controls are in place, nutrient loading to the lake may be so great that harvesting aquatic vegetation may be required regularly to allow use of the lake. We will not generally consider a project for aquatic plant harvesting unless it will result in long lasting improvements.

A few commenters were confused regarding the relationship between 208 State and areawide wastewater management planning and the eligibility of a State to receive section 314 support. Section 208 planning does not have to be approved for a State to receive clean lakes assistance. If a 208 plan has been approved, the pertinent and applicable pollution controls identified in the 208 plan must be included in a clean lakes implementation plan. If a 208 plan has not been approved but has been developed, the pertinent and applicable pollution controls identified in the 208 plan should be included in the clean lakes project. If there is no 208 planning, then the lake protection and restoration procedures developed under a section 314 project should be consistent with 208 planning procedures so that the lake restoration planning can be included in any future 208 planning activities for the particular lake area.

In order to assure that these procedures are followed, States must certify under § 35.1620-2(a), that a project is consistent with the State Water Quality Management work program (see § 35.1513). Under § 35.1620-2(b), Phase 1 applications shall include written certification from the appropriate areawide or State 208 planning agency that work conducted under the proposed project will not duplicate work completed under any 208 planning grant, and that the applicant proposes to use any applicable approved 208 planning in the clean lakes project design. Under § 35.1620-2(c), Phase 2 applications must contain written certification from appropriate areawide or State 208 planning agencies that the proposed Phase 2 lake restoration proposal is consistent with any approved 208 planning.

One commenter suggested that 314 funding should be restricted so that it is not used to enhance boating or onshore recreational opportunities. EPA did not include these restrictions in the regulations for a variety of reasons. Lakes are traditionally used as recreational sites by the general public, and the degradation of those recreational sites through water pollution prompted the Congress to include section 314 in the Clean Water Act. EPA is supportive of the multiple use concept in the use of public funds. Frequently, the heavy use of the immediate lake shore will promote excessive pollutant loading, e.g., sediment and plant nutrients. In some cases, outright purchase of these lands to provide buffer strips is the most effective method of pollution control. Often lake shores can be used for low intensity recreational activities. Similarly, land abutting the lake may be purchased to provide an area to build a lake treatment structure and these areas should be considered for recreational opportunities.

Since recreational opportunities and water quality can sometimes be improved by removal of accumulated lake sediments, it would be inappropriate for EPA to ban dredging as an element of a comprehensive lake restoration project solely because it would benefit recreational activities.

As a means to assure that adverse environmental impact mitigation procedures are implemented in a lake restoration project, we have removed the 20 percent restriction on the cost of mitigation activities. All necessary mitigation activities should be included in the project. If mitigation costs are excessive, then the public benefits, when evaluated against project costs, will be lower and a proposed project will have lower priority for funding.

Conditions on Award

Numerous commenters were concerned about payment of the non-Federal share of a project by the State. We have modified § 35.1650-3(a)(2) to allow a State to arrange financing through substate financial agreements.

We understand that in many instances local agencies will be providing some or all of the required non-Federal matching share for clean lakes projects. It should be noted that as the only eligible award recipient, the State assumes the ultimate responsibility for the non-Federal share.

Some commenters argued that the monitoring program required under Appendix A (b)(3) is defined too rigidly. We agree, so we have modified the regulation to allow States and project officers to negotiate a program that is appropriate for each project.

Most commenters on the award conditions believe the requirement that States must maintain a project for ten years after a project is completed is excessive. We believe that States should agree to an operation and maintenance program that would assure that effective pollution controls are maintained to maximize the benefits in relation to the cost of the project. We believe that 10 years is a reasonable amount of time. Because we have no data to defend the cost effectiveness of this condition, it has been modified to cover only the project period. We believe the commitment by a State to an effective operation and maintenance program in the post project period is important and should be given special consideration in the evaluation of project proposals. Therefore, the evaluation criteria have been modified in § 35.1640–1 to include an assessment of the adequateness of the proposed post project operation and maintenance program.

We have changed section 35.1650–3(b) to allow Phase 1 recipients to negotiate with the project officer the project scope of work that is stated in section (a)(10) of Appendix A. Many commenters argued that the information required by section (a)(10) should be determined on a case by case basis. We believe that flexibility is desirable and will minimize project costs without sacrificing program integrity and public benefits. Similarly, we have modified § 35.1650–3(c) to allow flexibility on the design of Phase 2 monitoring programs to fulfill the requirement of section (b)(3) of Appendix A. Again, EPA project officer approval is required before the scope of work can be modified.

EPA received a significant number of comments on the reporting requirements in § 35.1650–5. The commenters were critical of the number of reports required and the amount of information required in Phase 1 project progress reports. Accordingly, we have modified the reporting requirements so that Phase 1 reports are only required semi-annually, and the final report will be the only Phase 1 report requiring the submission of water quality data. The frequency of Phase 2 reporting will not exceed quarterly and will be based on the complexity of the project. The reporting requirement will be stipulated in the cooperative agreement.

Several commenters requested clarification of subsection (a)(7) of Appendix A. We believe that recipients and EPA should have sufficient information about the usability of other lakes in proximity to the project lake to evaluate the benefits in relation to the costs of a proposed project. The funds available to support lake protection and restoration activities are limited. Information required by subsection (a)(7) should be helpful to States in establishing priorities for projects. The regulations do not require States to conduct exhaustive surveys of lake resources within a 80 kilometer radius of the project lake, but we do need an understanding of similar lake use opportunities in that distance to assure appropriate use of public funds.

A few comments concerned the procedures used to determine the limiting nutrient in lakes. Section (a)(10) of Appendix A requires the calculation of total nitrogen to total phosphorus ratios and/or the use of the algal assay bottle tests. One commenter stated that the algal assay bottle test should be a required procedure. Although the bottle test is an excellent investigative procedure, we believe that many States lack the appropriate equipment to perform these analyses and the costs would be excessive in some cases. Other commenters suggested that other forms of nitrogen and phosphorus should be used to calculate the N/P ratio. We are aware of the significant controversy over the appropriateness and reproducibility of tests using other fractional chemical forms of these nutrients. EPA believes that at this time, the total nitrogen and total phosphorus ratio is the most desirable test. Appendix A calls for the measurement of several chemical forms of these nutrients. Investigators and EPA may wish to calculate other ratios in addition to total nitrogen to total phosphorus using these measurements.

Since the publication of the proposed rules, EPA's Administrator on June 14, 1979, signed a memorandum to assure that all environmental measurements done with EPA funding result in usable data of known quality. Any clean lakes cooperative agreements awarded after OMB approves the Administrator's directive under the Federal Reports Act will contain a condition requiring compliance.

State/EPA Agreement

In these and other regulations, we are developing the concept of a State/EPA Agreement. The Agreement will provide a way for EPA Regional Administrators and States to coordinate a variety of programs under the Clean Water Act, the Resource Conservation and Recovery Act, the Safe Drinking Water Act and other laws administered by EPA. This subpart governs only that part of the State/EPA Agreement which relates to cooperative agreements under the clean lakes program. Other programs included in the State/EPA Agreement will be governed by provisions found elsewhere in this chapter. Beginning in FY 1980, State programs funded under section 314 of the Act will be part of the State/EPA Agreement and the State/EPA Agreement must be completed before grant award. EPA will issue guidance concerning the development and the content of the State/EPA Agreement.

Regulatory Analysis

We have determined that this regulation does not require regulatory analysis under Executive Order 12044.

Evaluation

Section 2(d)(8) of Executive Order 12044 requires that each regulation be accompanied by a plan for evaluating a regulation after it issued. In order to comply with this requirement, EPA will conduct an evaluation of this regulation which will either be presented in the section 304(j) report, which is scheduled to be published in December 1981, or published separately.

Dated: January 28, 1980.

Douglas M. Costle,

Administrator.

PART 35, SUBPART H ADDED

EPA is amending Title 40 of the Code of Federal Regulations by adding a new Subpart H to Part 35 to read as follows:

PART 35—STATE AND LOCAL ASSISTANCE

* * * * *

Subpart H—Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes

Sec.

Authority: Secs. 314 and 501, Clean Water Act (86 Stat. 816; 33 U.S.C. 1251 *et seq.*)

Subpart H—Cooperative Agreements For Protecting and Restoring Publicly Owned Freshwater Lakes

§ 35.1600 Purpose.

This subpart supplements the EPA general grant regulations and procedures (Part 30 of this chapter) and establishes policies and procedures for cooperative agreements to assist States in carrying out approved methods and procedures for restoration (including protection against degradation) of publicly owned freshwater lakes.

§ 35.1603 Summary of clean lakes assistance program.

(a) Under section 314 of the Clean Water Act, EPA may provide financial assistance to States to implement methods and procedures to protect and restore publicly owned freshwater lakes. Although cooperative agreements may be awarded only to States, these regulations allow States, through substate agreements, to delegate some or all of the required work to substate agencies.

(b) Only projects that deal with publicly owned freshwater lakes are eligible for assistance. The State must have assigned a priority to restore the lake, and the State must certify that the lake project is consistent with the State Water Quality Management Plan (§ 35.1521) developed under the State/EPA Agreement. The State/EPA Agreement is a mechanism for EPA Regional Administrators and States to coordinate a variety of programs under the Clean Water Act, the Resource Conservation and Recovery Act, the Safe Drinking Water Act and other laws administered by EPA.

(c) These regulations provide for Phase 1 and 2 cooperative agreements. The purpose of a Phase 1 cooperative agreement is to allow a State to conduct a diagnostic-feasibility study to determine a lake's quality, evaluate possible solutions to existing pollution problems, and recommend a feasible program to restore or preserve the quality of the lake. A Phase 2 cooperative agreement is to be used for implementing recommended methods and procedures for controlling pollution entering the lake and restoring the lake. EPA award of Phase 1 assistance does not obligate EPA to award Phase 2 assistance for that project. Additionally, a Phase 1 award is not a prerequisite for receiving a Phase 2 award. However, a Phase 2 application for a proposed project that was not evaluated under a Phase 1 project shall contain the information required by Appendix A.

(d) EPA will evaluate all applications in accordance with the application review criteria of § 35.1640–1. The review criteria include technical feasibility, public benefit, reasonableness of proposed costs, environmental impact, and the State's priority ranking of the lake project.

(e) Before awarding funding assistance, the Regional Administrator shall determine that pollution control measures in the lake watershed authorized by section 201, included in an approved 208 plan, or required by section 402 of the Act are completed or are being implemented according to a schedule that is included in an approved plan or discharge permit. Clean lakes funds may not be used to control the discharge of pollutants from a point source where the cause of pollution can be alleviated through a municipal or industrial permit under section 402 of the Act or through the planning and construction of wastewater treatment facilities under section 201 of the Act.

§ 35.1605 Definitions.

The terms used in this subpart have the meanings defined in section 502 of the Act. In addition, the following terms shall have the meaning set forth below.

§ 35.1605–1 The Act.

The Clean Water Act, as amended (33 U.S.C. 1251 *et seq.*).

§ 35.1605–2 Freshwater lake.

Any inland pond, reservoir, impoundment, or other similar body of water that has recreational value, that exhibits no oceanic and tidal influences, and that has a total dissolved solids concentration of less than 1 percent.

§ 35.1605–3 Publicly owned freshwater lake.

A freshwater lake that offers publi access to the lake through publicly owned contiguous land so that any person has the same opportunity to enjoy non-consumptive privileges an benefits of the lake as any other pers If user fees are charged for public use and access through State or substate operated facilities, the fees must be u for maintaining the public access and recreational facilities of this lake or other publicly owned freshwater lake in the State, or for improving the qual of these lakes.

§ 35.1605–4 Nonpoint source.

Pollution sources which generally a not controlled by establishing effluen limitations under sections 301, 302, a 402 of the Act. Nonpoint source pollutants are not traceable to a disc identifiable origin, but generally resu from land runoff, precipitation, drain or seepage.

§ 35.1605–5 Eutrophic lake.

A lake that exhibits any of the following characteristics: (a) Excessi biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallow or (c) seasonal and/or diurnal dissol oxygen deficiencies that may cause obnoxious odors, fish kills, or a shift the composition of aquatic fauna to l desirable forms.

§ 35.1605–6 Trophic condition.

A relative description of a lake's biological productivity based on the availability of plant nutrients. The ra of trophic conditions is characterized the terms of oligotrophic for the least biologically productive, to eutrophic the most biologically productive.

§ 35.1605–7 Desalinization.

Any mechanical procedure or proc where some or all of the salt is remo from lake water and the freshwater portion is returned to the lake.

§ 35.1605–8 Diagnostic-feasibility stud

A two part study to determine a la current condition and to develop possible methods for lake restoration and protection.

(a) The diagnostic portion of the st includes gathering information and d to determine the limnological, morphological, demographic, socio-economic, and other pertinent characteristics of the lake and its watershed. This information will provide recipients an understanding the quality of the lake, specifying the location and loading characteristics of significant sources polluting the lake.

(b) The feasibility portion of the study includes: (1) Analyzing the diagnostic information to define methods and procedures for controlling the sources of pollution; (2) determining the most energy and cost efficient procedures to improve the quality of the lake for maximum public benefit; (3) developing a technical plan and milestone schedule for implementing pollution control measures and in-lake restoration procedures; and (4) if necessary, conducting pilot scale evaluations.

§ 35.1610 Eligibility.

EPA shall award cooperative agreements for restoring publicly owned freshwater lakes only to the State agency designated by the State's Chief Executive. The award will be for projects which meet the requirements of this subchapter.

§ 35.1613 Distribution of funds.

(a) For each fiscal year EPA will notify each Regional Administrator of the amount of funds targeted for each Region through annual clean lakes program guidance. To assure an equitable distribution of funds the targeted amounts will be based on the clean lakes program which States identify in their State WQM work programs.

(b) EPA may set aside up to twenty percent of the annual appropriations for Phase 1 projects.

§ 35.1615 Substate agreements.

States may make financial assistance available to substate agencies by means of a written interagency agreement transferring project funds from the State to those agencies. The agreement shall be developed, administered and approved in accordance with the provisions of 40 CFR 33.240 (Intergovernmental agreements). A State may enter into an agreement with a substate agency to perform all or a portion of the work under a clean lakes cooperative agreement. Recipients shall submit copies of all interagency agreements to the Regional Administrator. If the sum involved exceeds $100,000, the agreement shall be approved by the Regional Administrator before funds are released by the State to the substate agency. The agreement shall incorporate by reference the provisions of this subchapter. The agreement shall specify outputs, milestone schedule, and the budget required to perform the associated work in the same manner as the cooperative agreement between the State and EPA.

§ 35.1620 Application requirements.

(a) EPA will process applications in accordance with Subpart B of Part 30 of this subchapter. Applicants for assistance under the clean lakes program shall submit EPA form 5700-33 (original with signature and two copies) to the appropriate EPA Regional Office (see 40 CFR 30.130).

(b) Before applying for assistance, applicants should contact the appropriate Regional Administrator to determine EPA's current funding capability.

§ 35.1620-1 Types of assistance.

EPA will provide assistance in two phases in the clean lakes program.

(a) *Phase 1—Diagnostic feasibility studies.* Phase 1 awards of up to $100,000 per award (requiring a 30 percent non-Federal share) are available to support diagnostic-feasibility studies (see Appendix A).

(b) *Phase 2—Implementation.* Phase 2 awards (requiring a 50 percent non-Federal share) are available to support the implementation of pollution control and/or in-lake restoration methods and procedures including final engineering design.

§ 35.1620-2 Contents of applications.

(a) All applications shall contain a written State certification that the project is consistent with State Water Quality Management work program (see § 35.1513 of this subchapter) and the State Comprehensive Outdoor Recreation Plan (if completed). Additionally, the State shall indicate the priority ranking for the particular project (see § 35.1620-5).

(b) Phase 1 applications shall contain: (1) A narrative statement describing the specific procedures that will be used by the recipient to conduct the diagnostic-feasibility study including a description of the public participation to be involved (see § 25.11 of this chapter);

(2) A milestone schedule;

(3) An itemized cost estimate including a justification for these costs;

(4) A written certification from the appropriate areawide or State 208 planning agency that the proposed work will not duplicate work completed under any 208 planning grant, and that the applicant is proposing to use any applicable approved 208 planning in the clean lakes project design; and

(5) For each lake being investigated, the information under subparagraph (5)(i) of this paragraph and, when available, the information under subparagraph (5)(ii) of this paragraph.

(i) Mandatory information.

(A) The legal name of the lake, reservoir, or pond.

(B) The location of the lake within the State, including the latitude and longitude, in degrees, minutes, and seconds of the approximate center of the lake.

(C) A description of the physical characteristics of the lake, including its maximum depth (in meters); its mean depth (in meters); its surface area (in hectares); its volume (in cubic meters); the presence or absence of stratified conditions; and major hydrologic inflows and outflows.

(D) A summary of available chemical and biological data demonstrating the past trends and current water quality of the lake.

(E) A description of the type and amount of public access to the lake, and the public benefits that would be derived by implementing pollution control and lake restoration procedures.

(F) A description of any recreational uses of the lake that are impaired due to degraded water quality. Indicate the cause of the impairment, such as algae, vascular aquatic plants, sediments, or other pollutants.

(G) A description of the local interests and fiscal resources committed to restoring the lake.

(H) A description of the proposed monitoring program to provide the information required in Appendix A paragraph (a)(10) of this section.

(ii) Discretionary information. States should submit this information when available to assist EPA in reviewing the application.

(A) A description of the lake watershed in terms of size, land use (list each major land use classification as a percentage of the whole), and the general topography, including major soil types.

(B) An identification of the major point source pollution discharges in the watershed. If the sources are currently controlled under the National Pollutant Discharge Elimination System (NPDES), include the permit numbers.

(C) An estimate of the percent contribution of total nutrient and sediment loading to the lake by the identified point sources.

(D) An indication of the major nonpoint sources in the watershed. If the sources are being controlled describe the control practice(s), including best land management practices.

(E) An indication of the lake restoration measures anticipated, including watershed management, and a projection of the net improvement in water quality.

(F) A statement of known or anticipated adverse environmental impacts resulting from lake restoration.

(c) Phase 2 applications shall include: (1) The information specified in Appendix A in a diagnostic/feasibility study or its equivalent; (2) certification by the appropriate areawide or State 208 planning agencies that the proposed Phase 2 lake restoration proposal is consistent with any approved 208 planning; and (3) copies of all issued permits or permit applications (including a summary of the status of applications) that are required for the discharge of dredged or fill material under section 404 of the Act.

§ 35.1620-3 Environmental evaluation.

Phase 2 applicants shall submit an evaluation of the environmental impacts of the proposed project in accordance with the requirements in Appendix A of this regulation.

§ 35.1620-4 Public participation.

(a) *General.* (1) In accordance with this Part and Part 25 of this chapter, the applicant shall provide for, encourage, and assist public participation in developing a proposed lake restoration project.

(2) Public consultation may be coordinated with related activities to enhance the economy, the effectiveness, and the timeliness of the effort, or to enhance the clarity of the issue. This procedure shall not discourage the widest possible participation by the public.

(b) *Phase 1.* (1) Phase 1 recipients shall solicit public comment in developing, evaluating, and selecting alternatives; in assessing potential adverse environmental impacts; and in identifying measures to mitigate any adverse impacts that were identified. The recipient shall provide information relevant to these decisions, in fact sheet or summary form, and distribute them to the public at least 30 days before selecting a proposed method of lake restoration. Recipients shall hold a formal or informal meeting with the public after all pertinent information is distributed, but before a lake restoration method is selected. If there is significant public interest in the cooperative agreement activity, an advisory group to study the process shall be formed in accordance with the requirements of § 25.3(d)(4) of this chapter.

(2) A formal public hearing shall be held if the Phase 1 recipient selects a lake restoration method that involves major construction, dredging, or significant modifications to the environment, or if the recipient or the Regional Administrator determines that a hearing would be beneficial.

(c) *Phase 2.* (1) A summary of the recipient's response to all public comments, along with copies of any written comments, shall be prepared and submitted to EPA with a Phase 2 application.

(2) Where a proposed project has not been studied under a Phase 1 cooperative agreement, the applicant for Phase 2 assistance shall provide an opportunity for public consultation with adequate and timely notices before submitting an application to EPA. The public shall be given the opportunity to discuss the proposed project, the alternatives, and any potentially adverse environmental impacts. A public hearing shall be held where the proposed project involves major construction, dredging or other significant modification of the environment. The applicant shall provide a summary of his responses to all public comments and submit the summary, along with copies of any written comments, with the application.

§ 35.1620-5 State work programs and lake priority lists.

(a)(1) A State shall submit to the Regional Administrator as part of its annual work program (§ 35.1513 of this subchapter) a description of the activities it will conduct during the Federal fiscal year to classify its lakes according to trophic condition (§ 35.1630) and to set priorities for implementing clean lakes projects within the State. The work plan must list in priority order the cooperative agreement applications that will be submitted by the State for Phase 1 and Phase 2 projects during the upcoming fiscal year, along with the rationale used to establish project priorities. Each State must also list the cooperative agreement applications, with necessary funding, which it expects to submit in the following fiscal year. This information will assist EPA in targeting resources under § 35.1613.

(2) A State may petition the Regional Administrator by letter to modify the EPA approved priority list established under paragraph (a)(1) of this section. This may be done at any time if the State believes there is sufficient justification to alter the priority list contained in its annual work program, e.g., if a community with a lower priority project has sufficient resources available to provide the required matching funding while a higher priority project does not, or if new data indicates that a lower priority lake will have greater public benefit than a higher priority lake.

(b) Clean lakes restoration priorities should be consistent with the Statewide water quality management strategy (see § 35.1511-2 of this subchapter). In establishing priorities on particular lake restoration projects, States should use as criteria the application review criteria (§ 35.1640-1) that EPA will use in preparing funding recommendations for specific projects. If a State chooses to use different criteria, the State should indicate this to the Regional Administrator as part of the annual work program.

§ 35.1620-6 State and local clearinghouse procedures.

In accordance with § 30.305 of this subchapter, all requirements of OMB Circular A-95 must be met before States submit applications to EPA.

§ 35.1630 State lake classification surveys.

States that wish to participate in the clean lakes program shall establish and submit to EPA by January 1, 1982, a classification, according to trophic condition, of their publicly owned freshwater lakes that are in need of restoration or protection. After December 31, 1981, States that have not complied with this requirement will not be eligible for Federal financial assistance under this subpart until they complete their survey.

§ 35.1640 Application review and evaluation.

EPA will review applications as they are received. EPA may request outside review by appropriate experts to assist with technical evaluation. Funding decisions will be based on the merit of each application in accordance with the application review criteria under § 35.1640-1. EPA will consider Phase 1 applications separately from Phase 2 applications.

§ 35.1640-1 Application review criteria.

(a) When evaluating applications, EPA will consider information supplied by the applicant which address the following criteria:

(1) The technical feasibility of the project, and where appropriate, the estimated improvement in lake water quality.

(2) The anticipated positive changes that the project would produce in the overall lake ecosystem, including the watershed, such as the net reduction in sediment, nutrient, and other pollutant loadings.

(3) The estimated improvement in fish and wildlife habitat and associated beneficial effects on specific fish populations of sport and commercial species.

(4) The extent of anticipated benefits to the public. EPA will consider such factors as (i) the degree, nature and sufficiency of public access to the lake;

(ii) the size and economic structure of the population residing near the lake which would use the improved lake for recreational and other purposes; (iii) the amount and kind of public transportation available for transport of the public to and from the public access points; (iv) whether other relatively clean publicly owned freshwater lakes within 80 kilometer radius already adequately serve the population; and (v) whether the restoration would benefit primarily the owners of private land adjacent to the lake.

(5) The degree to which the project considers the "open space" policies contained in sections 201(f), 201(g), and 208(b)(2)(A) of the Act.

(6) The reasonableness of the proposed costs relative to the proposed work, the likelihood that the project will succeed, and the potential public benefits.

(7) The means for controlling adverse environmental impacts which would result from the proposed restoration of the lake. EPA will give specific attention to the environmental concerns listed in Section (c) of Appendix A.

(8) The State priority ranking for a particular project.

(9) The State's operation and maintenance program to ensure that the pollution control measures and/or in-lake restorative techniques supported under the project will be continued after the project is completed.

(b) For Phase 1 applications, the review criteria presented in paragraph (a) of this section will be modified in relation to the smaller amount of technical information and analysis that is available in the application. Specifically, under criterion (a)(1), EPA will consider a technical assessment of the proposed project approach to meet the requirements stated in Appendix A to this regulation. Under criterion (a)(4), EPA will consider the degree of public access to the lake and the public benefit. Under criterion (a)(7), EPA will consider known or anticipated adverse environmental impacts identified in the application or that EPA can presume will occur. Criterion (a)(9) will not be considered.

§ 35.1650 Award.

(a) Under 40 CFR 30.345, generally 90 days after EPA has received a complete application, the application will either be: (1) Approved for funding in an amount determined to be appropriate for the project; (2) returned to the applicant due to lack of funding; or (3) disapproved. The applicant shall be promptly notified in writing by the EPA Regional Administrator of any funding decisions.

(b) Applications that are disapproved can be submitted as new applications to EPA if the State resolves the issues identified during EPA review.

§ 35.1650-1 Project period.

(a) The project period for Phase 1 projects shall not exceed three years.

(b) The project period for Phase 2 projects shall not exceed four years. Implementation of complex projects and projects incorporating major construction may have longer project periods if approved by the Regional Administrator.

§ 35.1650-2 Limitations on awards.

(a) Before awarding assistance, the Regional Administrator shall determine that:

(1) The applicant has met all of the applicable requirements of § 35.1620 and § 35.1630; and

(2) State programs under section 314 of the Act are part of a State/EPA Agreement which shall be completed before the project is awarded.

(b) Before awarding Phase 2 projects, the Regional Administrator shall further determine that:

(1) When a Phase 1 project was awarded, the final report prepared under Phase 1 is used by the applicant to apply for Phase 2 assistance. The lake restoration plan selected under the Phase 1 project must be implemented under a Phase 2 cooperative agreement.

(2) Pollution control measures in the lake watershed authorized by section 201, included in an approved 208 plan, or required by section 402 of the Act have been completed or are being implemented according to a schedule that is included in an approved plan or discharge permit.

(3) The project does not include costs for controlling point source discharges of pollutants where those sources can be alleviated by permits issued under section 402 of the Act, or by the planning and construction of wastewater treatment facilities under section 201 of the Act.

(4) The State has appropriately considered the "open space" policy presented in sections 201(f), 201(g)(6), and 208(b)(2)(A) of the Act in any wastewater management activities being implemented by them in the lake watershed.

(5)(i) The project does not include costs for harvesting aquatic vegetation, or for chemical treatment to alleviate temporarily the symptoms of eutrophication, or for operating and maintaining lake aeration devices, or for providing similar palliative methods and procedures, unless these procedures are the most energy efficient or cost effective lake restorative method. (ii) Palliative approaches can be supported only where pollution in the lake watershed has been controlled to the greatest practicable extent, and where such methods and procedures are a necessary part of a project during the project period. EPA will determine the eligibility of such a project, based on the applicant's justification for the proposed restoration, the estimated time period for improved lake water quality, and public benefits associated with the restoration.

(6) The project does not include costs for desalinization procedures for naturally saline lakes.

(7) The project does not include costs for purchasing or long term leasing of land used solely to provide public access to a lake.

(8) The project does not include costs resulting from litigation against the recipient by EPA.

(9) The project does not include costs for measures to mitigate adverse environmental impacts that are not identified in the approved project scope of work. (EPA may allow additional costs for mitigation after it has reevaluated the cost-effectiveness of the selected alternative and has approved a request for an increase from the recipient.)

§ 35.1650-3 Conditions on award.

(a) *All awards.* (1) All assistance awarded under the Clean Lakes program is subject to the EPA General Grant conditions (Subpart C and Appendix A of Part 30 of this chapter). (2) For each clean lakes project the State agrees to pay or arrange the payment of the non-Federal share of the project costs.

(b) *Phase 1.* Phase 1 projects are subject to the following conditions:

(1) The recipient must receive EPA project officer approval on any changes to satisfy the requirements of (a)(10) of Appendix A before undertaking any other work under the grant.

(2) (i) Before selecting the best alternative for controlling pollution and improving the lake, as required in paragraph (b)(1) of Appendix A of this regulation, and before undertaking any other work stated under paragraph (b) of Appendix A, the recipient shall submit an interim report to the project officer. The interim report must include a discussion of the various available alternatives and a technical justification for the alternative that the recipient will probably choose. The report must include a summary of the public involvement and the comments that occurred during the development of the alternatives. (ii) The recipient must obtain EPA project officer approval of

the selected alternative before conducting additional work under the project.

(c) *Phase 2.* Phase 2 projects are subject to the following conditions:

(1) (i) The State shall monitor the project to provide data necessary to evaluate the efficiency of the project as jointly agreed to and approved by the EPA project officer. The monitoring program described in paragraph (b)(3) of Appendix A of this regulation as well as any specific measurements that would be necessary to assess specific aspects of the project, must be considered during the development of a monitoring program and schedule. The project recipient shall receive the approval of the EPA project officer for a monitoring program and schedule to satisfy the requirements of Appendix A paragraph (b)(3) before undertaking any other work under the project. (ii) Phase 2 projects shall be monitored for at least one year after construction or pollution control practices are completed.

(2) The State shall manage and maintain the project so that all pollution control measures supported under the project will be continued during the project period at the same level of efficiency as when they were implemented. The State will provide reports regarding project maintenance as required in the cooperative agreement.

(3) The State shall upgrade its water quality standards to reflect a higher water quality use classification if the higher water quality use was achieved as a result of the project (see 40 CFR 35.1550(c)(2)).

(4) If an approved project allows purchases of equipment for lake maintenance, such as weed harvesters, aeration equipment, and laboratory equipment, the State shall maintain and operate the equipment according to an approved lake maintenance plan for a period specified in the cooperative agreement. In no case shall that period be for less than the time it takes to completely amortize the equipment.

(5) If primary adverse environmental impacts result from implementing approved lake restoration or protection procedures, the State shall include measures to mitigate these adverse impacts at part of the work under the project.

(6) If adverse impacts could result to unrecorded archeological sites, the State shall stop work or modify work plans to protect these sites in accordance with the National Historic Preservation Act. (EPA may allow additional costs for ensuring proper protection of unrecorded archeological sites in the project area after reevaluating the cost effectiveness of the procedures and approving a request for a cost increase from the recipient.)

(7) If a project involves construction or dredging that requires a section 404 permit for the discharge of dredged or fill material, the recipient shall obtain the necessary section 404 permits before performing any dredge or fill work.

§ 35.1650-4 Payment.

(a) Under § 30.615 of this chapter, EPA generally will make payments through letter of credit. However, the Regional Administrator may place any recipient on advance payment or on cost reimbursement, as necessary.

(b) Phase 2 projects involving construction of facilities or dredging and filling activities shall be paid by reimbursement.

§ 35.1650-5 Allowable costs.

(a) The State will be paid under § 35.1650-4 for the Federal share of all necessary costs within the scope of the approved project and determined to be allowable under 40 CFR 30.705, the provisions of this subpart, and the cooperative agreement.

(b) Costs for restoring lakes used solely for drinking water supplies are not allowable under the Clean Lakes Program.

§ 35.1650-6 Reports.

(a) States with Phase 1 projects shall submit semi-annual progress reports (original and one copy) to the EPA project officer within 30 days after the end of every other standard quarter. Standard quarters end on March 31, June 30, September 30, and December 31. These reports shall include the following:

(1) Work progress relative to the milestone schedule, and difficulties encountered during the previous six months.

(2) A brief discussion of the project findings appropriate to the work conducted during the previous six months.

(3) A report of expenditures in the past six months and those anticipated in the next six months.

(b) *Phase 2.* States with Phase 2 projects shall submit progress reports (original and one copy) according to the schedule established in the cooperative agreement. The frequency of Phase 2 project progress reports shall be determined by the size and complexity of the project, and shall be required no more frequently than quarterly. The Phase 2 progress report shall contain all of the information required for Phase 1 progress reports indicated in paragraph (a) of this section. This report also must include water quality monitoring data and a discussion of the changes in water quality which appear to have resulted from the lake restoration activities implemented during the reporting period.

(c) *Final Report.* States shall prepare a final report for all grants in accordance with § 30.635-2 of this subchapter. Phase 1 reports shall be organized according to the outline of information requirements stated in Appendix A. All water quality data obtained under the grant shall be submitted in the final report. Phase 2 reports shall conform to the format presented in the EPA manual on "Scientific and Technical Publications," May 14, 1974, as revised or updated. The States shall submit the report within 90 days after the project is completed.

(d) *Financial Status Report.* Within 90 days after the end of each budget period, the grantee shall submit to the Regional Administrator an annual report of all expenditures (Federal and non-Federal) which accrued during the budget period. Beginning in the second quarter of any succeeding budget period, payments may be withheld under § 30.615-3 of this chapter until this report is received.

Appendix A—Requirements for Diagnostic-Feasibility Studies and Environmental Evaluations

Phase 1 clean lakes projects shall include in their scope of work at least the following requirements, preferably in the order presented and under appropriate subheadings. The information required by paragraph (a)(10) and the monitoring procedures stated in paragraph (b)(3) of this Appendix may be modified to conform to specific project requirements to reduce project costs without jeopardizing adequacy of technical information or the integrity of the project. All modifications must be approved by the EPA project officer as specified in §§ 35.1650-3(b)(1) and 35.1650-3(c)(1).

(a) A diagnostic study consisting of:

(1) An identification of the lake to be restored or studied, including the name, the State in which it is located, the location within the State, the general hydrologic relationship to associated upstream and downstream waters and the approved State water quality standards for the lake.

(2) A geological description of the drainage basin including soil types and soil loss to stream courses that are tributary to the lake.

(3) A description of the public access to the lake including the amount and type of public transportation to the access points.

(4) A description of the size and economic structure of the population residing near the lake which would use the improved lake for recreation and other purposes.

(5) A summary of historical lake uses, including recreational uses up to the present time, and how these uses may have changed because of water quality degradation.

(6) An explanation, if a particular segment of the lake user population is or will be more adversely impacted by lake degradation.

(7) A statement regarding the water use of the lake compared to other lakes within a 80 kilometer radius.

(8) An itemized inventory of known point source pollution discharges affecting or which have affected lake water quality over the past 5 years, and the abatement actions for these discharges that have been taken, or are in progress. If corrective action for the pollution sources is contemplated in the future, the time period should be specified.

(9) A description of the land uses in the lake watershed, listing each land use classification as a percentage of the whole and discussing the amount of nonpoint pollutant loading produced by each category.

(10) A discussion and analysis of historical baseline limnological data and one year of current limnological data. The monitoring schedule presented in paragraph (b)(3) of Appendix A must be followed in obtaining the one year of current limnological data. This presentation shall include the present trophic condition of the lake as well as its surface area (hectares), maximum depth (meters), average depth (meters), hydraulic residence time, the area of the watershed draining to the lake (hectares), and the physical, chemical, and biological quality of the lake and important lake tributary waters. Bathymetric maps should be provided. If dredging is expected to be included in the restoration activities, representative bottom sediment core samples shall be collected and analyzed using methods approved by the EPA project officer for phosphorus, nitrogen, heavy metals, other chemicals appropriate to State water quality standards, and persistent synthetic organic chemicals where appropriate. Further, the elutriate must be subjected to test procedures developed by the U.S. Army Corps of Engineers and analyzed for the same constituents. An assessment of the phosphorus (and nitrogen when it is the limiting lake nutrient) inflows and outflows associated with the lake and a hydraulic budget including ground water flow must be included. Vertical temperature and dissolved oxygen data must be included for the lake to determine if the hypolimnion becomes anaerobic and, if so, for how long and over what extent of the bottom. Total and soluble reactive phosphorus (P); and nitrite, nitrate, ammonia and organic nitrogen (N) concentratons must be determined for the lake. Chlorophyll *a* values should be measured for the upper mixing zone. Representative alkalinities should be determined. Algal assay bottle test data or total N to total P ratios should be used to define the growth limiting nutrient. The extent of algal blooms, and the predominant algal genera must be discussed. Algal biomass should be determined through algal genera identification, cell density counts (numbers of cells per milliliter) and converted to cell volume based on factors derived from direct measurements; and reported in biomass of each major genus identified. Secchi disk depth and suspended solids should be measured and reported. The portion of the shoreline and bottom that is impacted by vascular plants (submersed, floating, or emersed higher aquatic vegetation) must be estimated, specifically the lake surface area between 0 and the 10 meter depth contour or twice the Secchi disk transparency depth, whichever is less, and that estimate should include an identification of the predominant species. Where a lake is subject to significant public contact use or is fished for consumptive purposes, monitoring for public health reasons should be part of the monitoring program. Standard bacteriological analyses and fish flesh analyses for organic and heavy metal contamination should be included.

(11) An identification and discussion of the biological resources in the lake, such as fish population, and a discussion of the major known ecological relationships.

(b) A feasibility study consisting of:

(1) An identification and discussion of the alternatives considered for pollution control or lake restoration and an identification and justification of the selected alternative. This should include a discussion of expected water quality improvement, technical feasibility, and estimated costs of each alternative. The discussion of each feasible alternative and the selected lake restoration procedure must include detailed descriptions specifying exactly what activities would be undertaken under each, showing how and where these procedures would be implemented, illustrating the engineering specifications that would be followed including preliminary engineering drawings to show in detail the construction aspects of the project, and presenting a quantitative analysis of the pollution control effectiveness and the lake water quality improvement that is anticipated.

(2) A discussion of the particular benefits expected to result from implementing the project, including new public water uses that may result from the enhanced water quality.

(3) A Phase 2 monitoring program indicating the water quality sampling schedule. A limited monitoring program must be maintained during project implementation, particularly during construction phases or in-lake treatment, to provide sufficient data that will allow the State and the EPA project officer to redirect the project if necessary, to ensure desired objectives are achieved. During pre-project, implementation, and post-project monitoring activities, a single in-lake site should be sampled monthly during the months of September through April and biweekly during May through August. This site must be located in an area that best represents the limnological properties of the lake, preferably the deepest point in the lake. Additional sampling sites may be warranted in cases where lake basin morphometry creates distinctly different hydrologic and limnologic sub-basins; or where major lake tributaries adversely affect lake water quality. The sampling schedule may be shifted according to seasonal differences at various latitudes. The biweekly samples must be scheduled to coincide with the period of elevated biological activity. If possible, a set of samples should be collected immediately following spring turnover of the lake. Samples must be collected between 0800 and 1600 hours of each sampling day unless diel studies are part of the monitoring program. Samples must be collected between one-half meter below the surface and one-half meter off the bottom, and must be collected at intervals of every one and one-half meters, or at six equal depth intervals, whichever number of samples is less. Collection and analyses of all samples must be conducted according to EPA approved methods. All of the samples collected must be analyzed for total and soluble reactive phosphorus; nitrite, nitrate, ammonia, and organic nitrogen; pH; temperature; and dissolved oxygen. Representative alkalinities should be determined. Samples collected in the upper mixing zone must be analyzed for chlorophyll *a*. Algal biomass in the upper mixing zone should be determined through algal genera

identification, cell density counts (number of cells per milliliter) and converted to cell volume based on factors derived from direct measurements; and reported in terms of biomass of each major genera identified. Secchi disk depth and suspended solids must be measured at each sampling period. The surface area of the lake covered by macrophytes between 0 and the 10 meter depth contour or twice the Secchi disk transparency depth, whichever is less, must be reported. The monitoring program for each clean lakes project must include all the required information mentioned above, in addition to any specific measurements that are found to be necessary to assess certain aspects of the project. Based on the information supplied by the Phase 2 project applicant and the technical evaluation of the proposal, a detailed monitoring program for Phase 2 will be established for each approved project and will be a condition of the cooperative agreement. Phase 2 projects will be monitored for at least one year after construction or pollution control practices are completed to evaluate project effectiveness.

(4) A proposed milestone work schedule for completing the project with a proposed budget and a payment schedule that is related to the milestone.

(5) A detailed description of how non-Federal funds will be obtained for the proposed project.

(6) A description of the relationship of the proposed project to pollution control programs such as the section 201 construction grants program, the section 208 areawide wastewater management program, the Department of Agriculture Soil Conservation Service and Agriculture Stabilization and Conservation Service programs, the Department of Housing and Urban Development block grant program, the Department of Interior Heritage Conservation and Recreation Service programs and any other local, State, regional and Federal programs that may be related to the proposed project. Copies of any pertinent correspondence, contracts, grant applications and permits associated with these programs should be provided to the EPA project officer.

(7) A summary of public participation in developing and assessing the proposed project which is in compliance with Part 25 of this chapter. The summary shall describe the matters brought before the public, the measures taken by the reporting agency to meet its responsibilities under Part 25 and related provisions elsewhere in this chapter, the public response, and the agency's response to significant comments. Part 25.8 responsiveness summaries may be used to meet appropriate portions of these requirements to avoid duplication.

(8) A description of the operation and maintenance plan that the State will follow, including the time frame over which this plan will be operated, to ensure that the pollution controls implemented during the project are continued after the project is completed.

(9) Copies of all permits or pending permit applications (including the status of such applications) necessary to satisfy the requirements of section 404 of the Act. If the approved project includes dredging activities or other activities requiring permits, the State must obtain from the U.S. Army Corps of Engineers or other agencies the permits required for the discharge of dredged or fill material under section 404 of the Act or other Federal, State or local requirements. Should additional information be required to obtain these permits, the State shall provide it. Copies of section 404 permit applications and any associated correspondence must be provide to the EPA project officer at the time they are submitted to the U.S. Army Corps of Engineers. After reviewing the 404 permit application, the project officer may provide recommendations for appropriate controls and treatment of supernatant derived from dredged material disposal sites to ensure the maximum effectiveness of lake restoration procedures.

(c) States shall complete and submit an environmental evaluation which considers the questions listed below. In many cases the questions cannot be satisfactorily answered with a mere "Yes" or "No". States are encouraged to address other considerations which they believe apply to their project.

(1) Will the proposed project displace any people?

(2) Will the proposed project deface existing residences or residential areas? What mitigative actions such as landscaping, screening, or buffer zones have been considered? Are they included?

(3) Will the proposed project be likely to lead to a change in established land use patterns, such as increased development pressure near the lake? To what extent and how will this change be controlled through land use planning, zoning, or through other methods?

(4) Will the proposed project adversly affect a significant amount of prime agricultural land or agricultural operations on such land?

(5) Will the proposed project result in a significant adverse effect on parkland, other public land, or lands of recognized scenic value?

(6) Has the State Historical Society or State Historical Preservation Officer been contacted? Has he responded, and if so, what was the nature of that response? Will the proposed project result in a significant adversely effect on lands or structures of historic, architectural, archaeological or cultural value?

(7) Will the proposed project lead to a significant long-range increase in energy demands?

(8) Will the proposed project result in significant and long range adverse changes in ambient air quality or noise levels? Short term?

(9) If the proposed project involves the use of in-lake chemical treatment, what long and short term adverse effects can be expected from that treatment? How will the project recipient mitigate these effects?

(10) Does the proposal contain all the information that EPA requires in order to determine whether the project complies with Executive Order 11988 on floodplains? Is the proposed project located in a floodplain? If so, will the project involve construction of structures in the floodplain? What steps will be taken to reduce the possible effects of flood damage to the project?

(11) If the project involves physically modifying the lake shore or its bed or its watershed, by dredging, for example, what steps will be taken to minimize any immediate and long term adverse effects of such activities? When dredging is employed, where will the dredged material be deposited, what ca[n] be expected and what measures will the recipient employ to minimize any significant adverse impacts from its deposition?

(12) Does the project proposal contain all information that EPA requires in order to determine whether the project complies with Executive Order 11990 on wetlands? Will the proposed project have a significant adverse effect on fish and wildlife, or on wetlands or any other wildife habitat, especially those o[f] endangered species? How significant is this impact in relation to the local or regional critical habitat needs? Have actions to mitigate habitat destruction been incorporated into the project? Has the recipient properly consulted with appropriate State and Federal fish, gam[e] and wildlife agencies and with the U.S. Fish and Wildlife Service? What were their replies?

(13) Describe any feasible alternativ[e] to the proposed project in terms of environmental impacts, commitment of resources, public interest and costs an[d] why they were not proposed.

(14) Describe other measures not discussed previously that are necessar[y] to mitigate adverse enivironmental impacts resulting from the implementation of the proposed projec[t]

APPENDIX F

PUBLIC PARTICIPATION SUMMARY

Summary of Public Participation

November 1, 1981

At this meeting, Project Manager Bill Jones met with the 9-member governing board of the Lake Lemon Civic Association (LLCA), a citizens group composed of and representing lakeshore homeowners. The LLCA members were informed of the work plan and timetable for the Phase I diagnostic/feasibility study. Several of the members provided historical information that proved useful in evaluating past conditions and management practices at the lake. The LLCA was particularly concerned about whether the Phase I study would interfere with plans to apply chemicals for weed control. Chemical applications were the primary tool used to control aquatic macrophytes prior to the initiation of this study.

Two of these LLCA members assisted us later in the project by making daily lake level elevation readings on staff gages that we attached to their piers.

March 1, 1983

A formal public meeting was held on this date to inform the public of the results of the study and to present the preliminary management recommendations. The meeting was held at the Unionville Elementary School, a public building located one mile from Lake Lemon. Announcements were made in the two local newspapers serving the watershed (Bloomington and Nashville) and on local radio stations. Brightly-colored posters announcing the meeting (see Figure F-1) were distributed to government buildings and supermarkets throughout the watershed.

Thirty-nine citizens attended the meeting in addition to our project personnel, City of Bloomington officials, and local newspaper, radio and television representatives. Slides, transparencies, and maps were used in summarizing the important findings of the study. The citizens asked questions concerning the costs of the recommended lake and watershed management practices and the sources of funding to pay for them. There was no opposition to the proposed management plan. The citizen's main concern was for controlling the rooted aquatic macrophytes in the lake and they didn't seem to have a preference for any particular method, as long as it was effective.

LAKE LEMON

PUBLIC MEETING

The results of a two-year, U.S. EPA-funded study by Indiana University's School of Public and Environmental Affairs (SPEA) and the City of Bloomington will be presented along with recommendations for managing Lake Lemon and its drainage basin.

WHEN:	**Tuesday, March 1, 1983** **7:30 P.M.**
WHERE:	**Unionville Elementary School cafeteria**
WHO:	**All persons interested in Lake Lemon and Beanblossom Creek are invited to attend.**

Figure F-1. Copy of poster used to advertise public meeting.

APPENDIX G

ENVIRONMENTAL EVALUATION

Appendix A of the Clean Lakes Program regulations includes a fourteen question environmental evaluation which must be completed before a Section 314 Phase II grant can be awarded. The questions and our responses appear below.

1. "Will the proposed project displace any people?"

   It is not anticipated that any people will have to be moved as a result of this project.

2. "Will the proposed project deface existing residences or residential areas? What mitigative actions such as landscaping, screening, or buffer zones have been considered? Are they included?"

   No residential areas will be defaced as a result of this project. The macrophyte harvesting program will improve the aesthetics of residences rather than deface them. The cut macrophyte unloading areas are well-shielded from residential views. Watershed management controls should not deface any residential properties but instead, are likely to enhance them.

3. "Will the proposed project be likely to lead to a change in established land use patterns, such as increased development pressure near the lake? To what extent and how will this change be controlled through land use planning, zoning, or through other methods?"

   Improved water quality of Lake Lemon, while making the lake more attractive to use, is not likely to significantly increase development pressure near the lake. Lake Lemon's water quality has not been a deterrent to additional development in the past. The availability of land to be developed is a greater constraint.

4. "Will the proposed project adversely affect a significant amount of prime agricultural land or agricultural operations on such land?"

   No land use changes will remove prime agricultural land from production as a result of this project. Operations on marginal land having steep slopes or lands along stream bottoms may be affected by management recommendations to reduce erosion and runoff.

5. "Will the proposed project result in a significant adverse effect on parkland, other public land, or lands of recognized scenic value?"

No significant adverse impacts are anticipated. The implementation of lake and watershed management programs will likely enhance the only parkland on the lake at Riddle Point.

6. "Has the State Historical Society or State Historical Preservation Officer been contacted? Has he responded, and if so, what was the nature of that response? Will the proposed project result in a significant adverse effect on lands or structures of historic, architectural, archaeological or cultural value?"

   The Indiana University Glen Black Laboratory for Archaeology was contacted during the study. While historical artifacts are likely to be located along most river bottoms and ridge tops in Monroe and Brown Counties, no significant sites will be affected by the proposed project.

7. "Will the proposed project lead to a significant long-range increase in energy demands?"

   The proposed project will not lead to a significant long-range increase in energy demands.

8. "Will the proposed project result in significant and long range adverse changes in ambient air quality or noise levels? Short term?"

   The mechanical harvester will not adversely affect air quality or noise levels.

9. "If the proposed project involves the use of in-lake chemical treatment, what long- and short term adverse effects can be expected from that treatment? How will the project recipient mitigate these effects?"

   No in-lake chemical treatments are recommended under the proposed plan.

10. "Does the proposal contain all the information that EPA requires in order to determine whether the project complies with Executive Order 11988 on floodplains? Is the proposed project located in a floodplain? If so, will the project involve construction of structures in the floodplain? What steps will be taken to reduce the possible effects of flood damage to the project?"

    The proposed plan recommends watershed management controls in the floodplain to reduce the possible effects of flood damage, e.g., buffer strips, streambank erosion controls. No other structures will be built in the floodplain.

11. "If the project involves physically modifying the lake shore or its bed or its watershed, by dredging, for example, what steps will be taken to minimize any immediate and long term adverse effects of such activities? When dredging is employed, where will the dredged material be deposited, what can be expected and what measures will the recipient employ to minimize any significant adverse impacts from its deposition?"

Dredging has not been proposed at this time for Lake Lemon. A complete assessment of potential adverse environmental impacts is strongly recommended should dredging be considered in the future.

12. "Does the project proposal contain all information that EPA requires in order to determine whether the project complies with Executive Order 11990 on wetlands? Will the proposed project have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species? How significant is this impact in relation to the local or regional critical habitat needs? Have actions to mitigate habitat destruction been incorporated into the project? Has the recipient properly consulted with appropriate State and Federal fish, game and wildlife agencies and with the U.S. Fish and Wildlife Service? What were their replies?"

Lake drawdown during the winter will expose some wetland areas in the eastern end of Lake Lemon. These wetlands have formed on sediment deltas near the mouth of Beanblossom Creek. Short-term drawdown should not significantly affect these wetlands, which are primarily composed of cattails and reed canary grass. Drawdown is likely to enhance the fisheries in Lake Lemon by putting increased predation pressure on the smaller fish. No endangered species were encountered in the Lake Lemon area, nor would they likely be adversely affected by the proposed project.

13. "Describe any feasible alternatives, to the proposed project in terms of environmental impacts, commitment of resources, public interest and costs and why they were not proposed."

The environmental impacts, costs, public interest, and resource requirements of all feasible alternatives are described elsewhere in this report (see Chapters 7 and 8 and Appendix F).

14. "Describe other measures not discussed previously that are necessary to mitigate adverse environmental impacts resulting from the implementation of the proposed project."

Measures designed to mitigate adverse environmental impacts resulting from this project are described in Chapters 8 and 9.

APPENDIX H

RESULTS OF SCS WATERSHED ASSESSMENT

AUG 19 REC'D

Bloomington

United States Department of Agriculture

Soil Conservation Service

Suite 2200
5610 Crawfordsville Rd.
Indianapolis, IN 46224

SUBJECT: PDM - Project Potential, Lake Lemon Watershed

Date: August 11, 1985

TO: Donald V. Wilson, Area Conservationist
SCS, Greencastle, IN

File Code: 390-0-5

Glynn Wilson, Assistant State Conservationist (WR); Walt Douglas, District Conservationist, Bloomington; Harold Thompson, Conservation Agronomist, Paoli; and I inspected subject watershed on August 6, 1985. The purpose of the inspection was to evaluate the watershed for its potential as a PL-566 watershed protection project.

In addition to the field inspection information from the following reports was considered:
1. Sedimentation of Lake Lemon, Monroe County, Indiana, by Edwin J. Hartke and John R. Hill, Indiana Geological Survey Occasional Paper 9. 1974.
2. Lake Lemon, Diagnostic Feasibility Report, Indiana University School of Public and Environmental Affairs, MAY, 1983 (DRAFT).

Lake Lemon is a 1440 acre reservoir constructed in northeastern Monroe County on Beanblossom Creek in 1953. The drainage area is about 44,900 acres (70.2 sq. miles), of which about 88 percent (39,600 acres) is in Brown County. The lake is shallow with a maximum depth of 28 feet and a mean depth of 9.7 feet. About 77 percent of the watershed is forested. Cropland and hayland/pasture comprise an estimated 19 percent of the drainage area. The original capacity of the reservoir was 14,400 acre feet. Problems that have been reported include high turbidity following storm events, sedimentation (especially in the eastern end of the lake), shoreline erosion, and a dense growth of Eurasion water milfoil.

The Geological Survey study indicated that the sedimentation rate in Lake Lemon from 1953 to 1973 was a relatively low 0.17 percent of its capacity per year (approximately 25 acre-feet/year), or a total of 3.4 percent over the 20 year period. Projecting that rate of sedimentation, the Geological Survey reported that the capacity of the lake would be reduced by one-half in 290 years. The attached copies of individual pages in the 1974 Geological Survey report graphically display the 1953-1973 sediment accumulation in Lake Lemon. The Indiana University study indicates that additional 1982 sediment survey work generally supports the 1973 data. This would suggest that in 29 years (1953-1982) the lake has lost 4.9 percent of its original capacity. Even though this rate is relatively low for lakes in this section of the country, the approximately 700 acre-feet of sediment accumulation is justifiably recognized as a lake management problem. The degree of impact that a watershed protection project could have on the lake is dependent upon the nature and severity of erosion in the watershed and the source of sediment.

A visual inspection of the watershed indicated that virtually all of the cropland is located in the nearly flat valley bottomland and on adjacent gently sloping areas. The steeper slopes are mostly forested with some hayland. There also exists several fields on the steeper slopes that may have been cultivated in the past but have presently reverted to idle land with relatively good vegetative cover. Erosion on the cropland does not appear to be particularly severe and is estimated to average about four to five tons per acre per year. Based upon field observations, the current land use is very good with respect to erosion control. However, the significant number of idle fields on sloping land may, at some previous time have been cultivated and yielded substantially more sediment than under current conditions. The Draft Indiana University report (page 133) revealed, based on questionnaires completed by lake residents, that "the majority of the older residents (more than 5 years at the lake) believe the lake's condition has gotten worse in the period they have lived on the lake. About four-fifths of those who lived on the lake less that 5 years felt the lake's condition has stayed the same or improved during that period of time."

A watershed protection project must address the problem via onfarm erosion control practices. However, erosion rates on cropland are not unusually severe and furthermore, cropland comprises roughly 20 percent or less of the watershed. Other sources of sediment that cannot be addressed through the watershed protection program are shoreline erosion from wave action, streambank erosion, roadside and road ditch erosion. Conservation tillage systems on the cropland would effectively reduce soil losses on the cropland. The on-going conservation program is administered by the Monroe County SWCD and Brown County SWCD. Watershed protection projects are approved only for those areas where the on-going programs, for a lack of adequate funding or staffing, cannot address the problem in a timely manner.

In summary, the erosion rates on cropland can be reduced by conservation tillage systems for which the local SWCDs and ASCS are currently providing assistance. Perhaps a public relations effort to emphasize these systems would be helpful in accelerating the rate of application. Some type of sediment trap in Beanblossom Creek to keep a large part of the bed load from reaching the lake may be a possibility. However, the operation and maintenance costs for a sediment trap are usually very high and a continuing cost. Also, most of the suspended load would pass through the trap and continue to reach the lake. Sediment traps for streams of this size are generally not within the expertise of Soil Conservation Service personnel.

The reduction in sediment yield from erosion of agricultural land can be accomplished through the on going program. Because of this, a PL-566 project for this watershed would not rate high in the competition for study approval. Special emphasis on conservation tillage systems through the on-going program should serve the interests of both the farm operators and Lake Lemon.

Charles J. Gossett
Water Resources Planning Staff Leader

Attachments

cc:
G. Wilson, Asst. State Conservationist (WR), SCS, Indianapolis, IN
Walt Douglas, District Conservationist, SCS, Bloomington, IN
Harold Thompson, Conservation Agronomist, SCS, Paoli, IN
J. Acres, Area Conservationist, Paoli, IN

CG/sh

APPENDIX I

LAKE MANAGEMENT PRODUCTS AND SUPPLIERS*

*mention of specific products or suppliers does not constitute endorsement by Indiana University or the U.S. EPA. This listing is not complete and is provided as a public service.

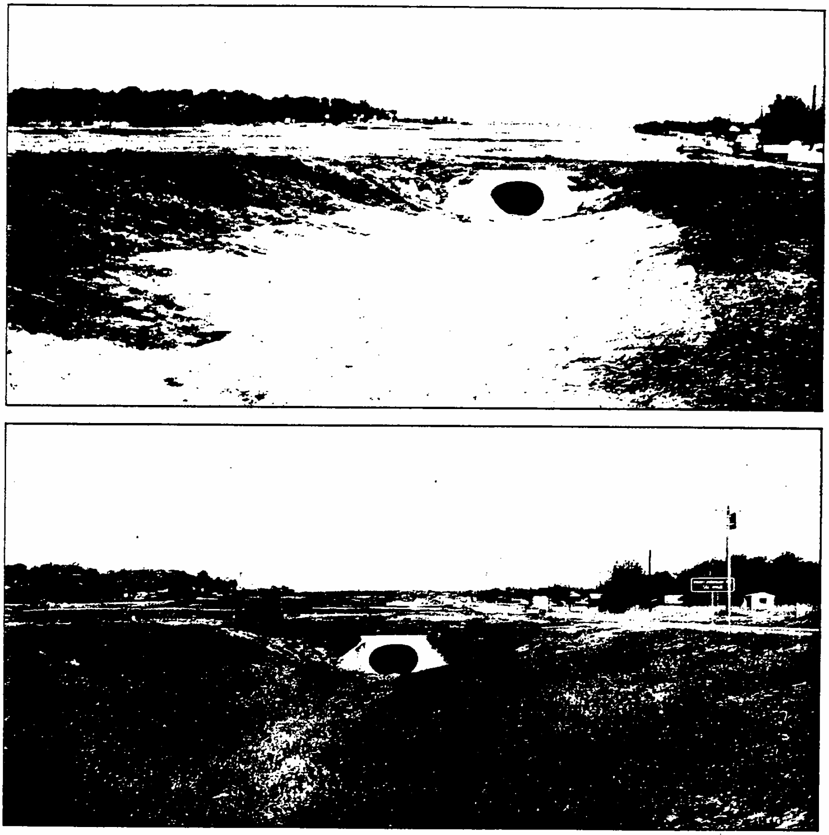
2.5 a/AL
2 ear
AE

AMERICAN EXCELSIOR COMPANY

I-1. Erosion control blankets.

Curlex® Blankets

Proven Performance in Erosion Control



Top Photo: Curlex Blankets protect this ditch on Highway 121 in North Texas. The photo was taken in the fall of 1982.
Bottom Photo: This shows the erosion free roadside ditch in the summer of 1983.

Curlex Blankets assist in seed germination, protect seedlings and control erosion by breaking up raindrops.

Curlex Blankets

MR/Manufacturer

American Excelsior Company with headquarters at Arlington, Texas is the world's largest producer of excelsior products, with 33 branch warehouses located coast to coast. In addition to Curlex Blankets, American Excelsior produces packing materials, excelsior for building board, concrete curing blankets and flexible urethane foam products for the home and industry.

UA/Uses and Application

Curlex Excelsior Blankets are designed to prevent erosion on:

- Steep slopes
- Berms
- Median strips
- Mine tailing sites
- Ditches
- Strip mine sites
- Ski slopes
- Dam sites
- Dikes
- Landscape projects or any other "hard to hold" problem area.

PP/Product Presentation

Now you can prevent erosion, assist in germination and protect seedlings with AMXCO Curlex Blankets.

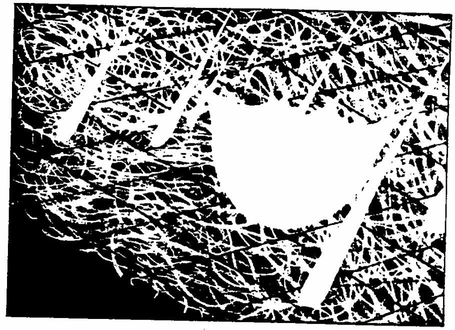
Curlex Blankets combine a dense mat of curled and seasoned Aspen wood excelsior with a tough, photodegradable plastic mesh. They are designed to halt erosion and will remain in place on even the roughest terrain.

Curlex blankets provide the ideal ground conditions for fast turf development. When properly installed, they retain moisture, control surface temperature fluctuations of the soil, conform to the terrain, protect against sun burnout and break up rain drops to stop erosion.

BARBING ACTION

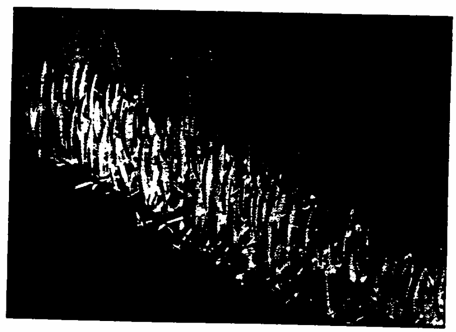
Rough edges shown in this magnified view of the curlex fibers show how fibers tend to cling together and form a tough mat over the soil surface.

OP/Overall Product



SHOCK ABSORPTION

The dense mat of curlex fibers and plastic netting arrest the destructive energy of rain drops, holds soil and seed in place, and helps establish vegetation.



VEGETATION PENETRATION

Vegetation growing through the curlex matting helps anchor the mat in place, with each blade of grass becoming another anchor point.

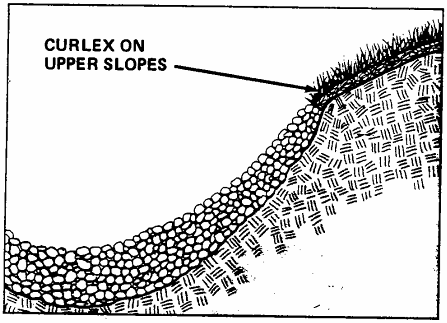
Slope Applications

2.5 a/A
2 ear
AE

Ditch Lining Applications

On large earth moving projects, erosion and sedimentation can be greatly reduced by the timely application of Curlex Blankets, singly or in combination with rip rap rock, gabions, concrete or asphalt.

▼



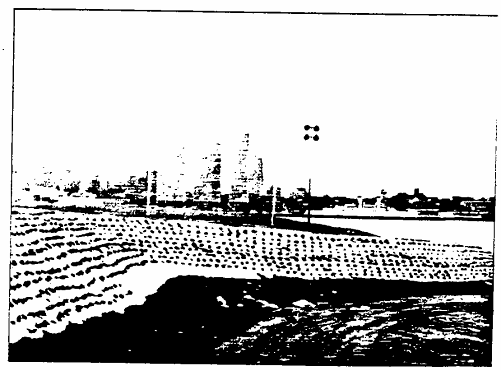
Curlex Blankets install easily and offer economical erosion protection

Value Engineering

▲ ***Iowa DOT roadside ditch protected with Curlex Blankets. Civil engineering fabric "check dams" assist in retarding water velocity. This method replaces expensive rock-lined ditches.***

▼ ***Same ditch, 6 months later. Another Curlex success story.***

▼ ***Versatile Curlex Blankets are used here in conjunction with ground cover on this steep hillside erosion project near Philadelphia.***



Suggested Specifications

APPLICATION

The area to be covered shall be properly prepared, fertilized and seeded before the blanket is applied. When the blanket is unrolled, the netting shall be on top and the fibers in contact with the soil over the entire area. In ditches the blankets shall be applied in the direction of the flow of water, butted snugly at ends and side and stapled. On slopes, the blankets shall be applied either horizontally or vertically to the slope. Ends and sides shall be butted snugly and stapled. It is not necessary to dig check slots, anchor ditches, or bury ends of Blankets.

MATERIAL

The Excelsior Blanket shall consist of a machine produced mat of curled wood excelsior of 80% six inch or longer fiber length, with consistent thickness and the fiber evenly distributed over the entire area of the blanket.

The top side of each blanket shall be covered with a photodegradable extruded plastic mesh. The blanket shall be made smolder resistant without the use of chemical additives.

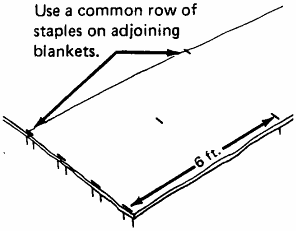
STAPLE

The Staples shall be made of wire, .091" in diameter or greater, "U" shaped with legs 6" in length and a 1" crown. Size and gauge of staples used will vary with soil conditions.

The Staples shall be driven vertically into the ground, spaced approximately two (2) lineal yards apart, on each side, and one row in the center alternately spaced between each side. (60 Staples on each Blanket) Use a common row of staples on adjoining blankets.

SLOPE INSTALLATION

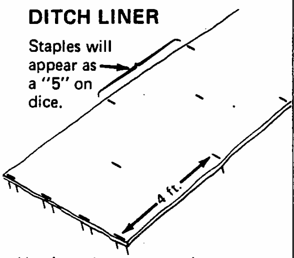
Use a common row of staples on adjoining blankets.



Use 4 staples across at the start of each roll and continue to staple throughout the length of the roll at 6 ft. intervals.

DITCH LINER

Staples will appear as a "5" on dice.



Use 4 staples across at the start of each roll and continue to staple throughout the length of the roll at 4 ft. intervals.

In areas with high water velocity, staples should be on 2 foot centers.

ROLL SIZE

Width .... 48 inches ± 1 inch
Length .... 180 feet average
Weight Per Roll... 78 pounds ± 10%
Square Yards Per Roll .. 80 average

AC-AVAILIBILITY, COSTS

SALES OFFICES LOCATED COAST TO COAST

Eastern Region

Atlanta Area
Woodbury, GA 30293
P.O. Box 669
(404) 553-5641

Baltimore Area
Annapolis Jct. MD 20701
P.O. Box 25
(301) 725-0464

Birmingham Area
Gardendale, AL 35071
2405 Decatur Hwy.
P.O. Box 945
(205) 631-2335

Boston Area
N. Chelmsford, MA 01863
100 Wotton Street
P.O. Box 97
(617) 251-7533

Cincinnati, OH 45216
415 W. Seymour Avenue
(513) 761-7384

Cleveland, OH 44114
3875 King Avenue
(216) 881-1122

Detroit Area
Westland, MI 48185
1210 Manufacturers Dr.
(313) 722-4540

Philadelphia Area
Norristown, PA 19404
P.O. Box 911
(215) 279-6970

Pittsburgh, PA 15208
214 N. Lexington Ave.
P.O. Box 56892
(412) 247-5414

Central Region

Chicago Area
Lombard, IL 60148
1111 North DuPage Avenue
(312) 627-3200

Dallas/Fort Worth Area
Arlington, TX 76011
900 Avenue H East
P.O. Box 5624
(817) 640-2161

Des Moines Area
Marshalltown, IA 50158
404 May Street
P.O. Box 897
(515) 753-8717

Houston, TX 77055
8375 Kempwood
(713) 464-3258

Indianapolis, IN 46202
814 N. Senate Ave.
(317) 634-3416

Minneapolis, MN 55414
3101 Talmadge Avenue, SE
(612) 331-1831

New Orleans, LA 70181
501 Coolidge Street
P.O. Box 10532
(504) 837-5834

North Kansas City, MO 64116
1400 Taney Street
P.O. Box 12320
(816) 842-3034

North Little Rock, AR 72119
800 Beech Street
P.O. Box 5818
(501) 375-5533

Oklahoma City, OK 73147
5011 West Reno
P.O. Box 75311
(405) 946-0512

St. Louis, MO 63132
1203 Ambassador Blvd.
P.O. Box 12414
(314) 993-5540

San Antonio, TX 78218
5424 Rittiman Plaza
(512) 822-8177

Sheboygan, WI 53081
1825 Erie Avenue
P.O. Box 249
(414) 458-4333

Western Region

Albuquerque, NM 87107
4019 Edith Boulevard, NE
P.O. Box 6494
(505) 345-7806

Amarillo, TX 79120
803 S. Garfield
P.O. Box 30249
(806) 373-8371

Denver, CO 80229
6475 North Franklin Street
(303) 287-3261

El Paso, TX 79923
3842 Durazno
P.O. Box 3641
(915) 542-1657

Fresno, CA 93745
4525 E. Commerce
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MACCAFERRI GABIONS

We are number one!

Instructions for Assembly and Erection

This publication presents the procedure for proper gabion installation. The method is quite simple; unskilled labor can be readily trained to perform the various tasks. If the proper procedures are followed, an economical, attractive, and structurally sound gabion installation will be assured. Technical literature describing the use of gabions for various applications is available on request. Maccaferri's technical staff is available to lend any assistance that may be required.

Supply and Delivery:

Gabions are supplied folded flat, tied in pairs and packed in bundles. For ease in handling, the number of gabions per bundle varies according to the size of the gabion. The gabions are identified by color stripes and by labels indicating their code size and dimensions. The lacing wire is supplied in coils.

If contract specification requires additional wiring extra coils may be ordered at reasonable cost.

Assembly:

Remove a single gabion from the bundle and proceed to unfold it on a hard flat surface. Stretch the gabion and stamp out all kinks (See Fig. No. 1). Fold the front and back panels to a right angle by stepping on the base along the crease. Fold up the end panels and diaphrams and fasten them to the front and back panels using the heavy gage wire projecting from the upper corners of each panel. This procedure will assure properly squared baskets with the tops of all panels even. Securely lace all vertical edges of ends and diaphrams. Use only Maccaferri connecting wire supplied for this purpose. No substitution of common wire is allowed, as this may not meet the specification requirements.

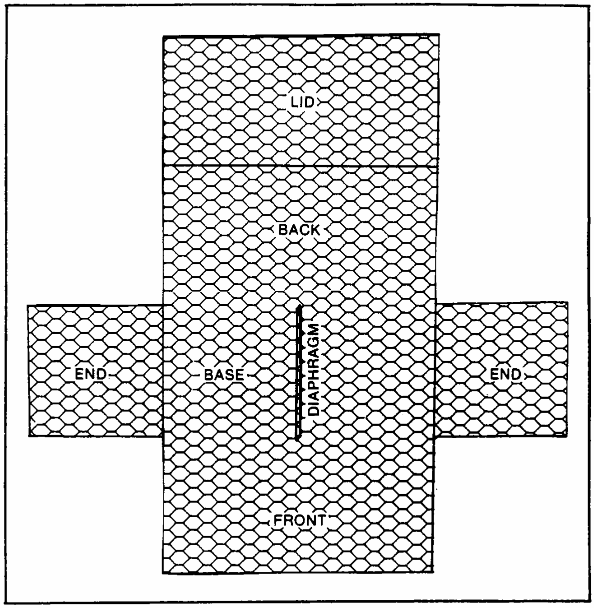

Fig. No. 1

The lacing procedure is as follows: cut a length of lacing wire approximately 1½ times the distance to be laced but not exceeding 5 feet. Secure the wire terminal at the corner by looping and twisting, then proceed lacing with single and double loops at approximately five (5) inch intervals (See Fig. No. 2). Securely fasten the other lacing wire terminal.

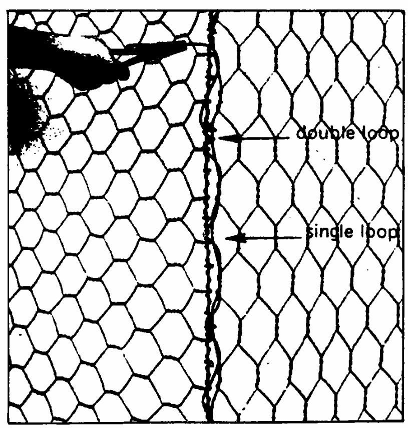

Fig. No. 2

Installation:

Before placing the gabions, it is necessary to make the ground surface relatively smooth and even.

The assembled gabions are carried to the job site and placed in their proper location. It is convenient to place the gabions front to front and back to back, as illustrated in Fig. No. 3, in order to expedite the stone filling and lid lacing operations.

For structural integrity, adjacent gabions must be laced along the perimeter of ALL contact surfaces.

To facilitate this operation it may be easier to construct sub-assemblies in the yard consisting of as many gabions as can be handled by the crew at one time. The sub-assembly is then placed at the job site and laced along the perimeter of ALL contact surfaces.

The base of the empty gabions placed on top of a completed row must also be tightly wired to the latter. (See blown up section).

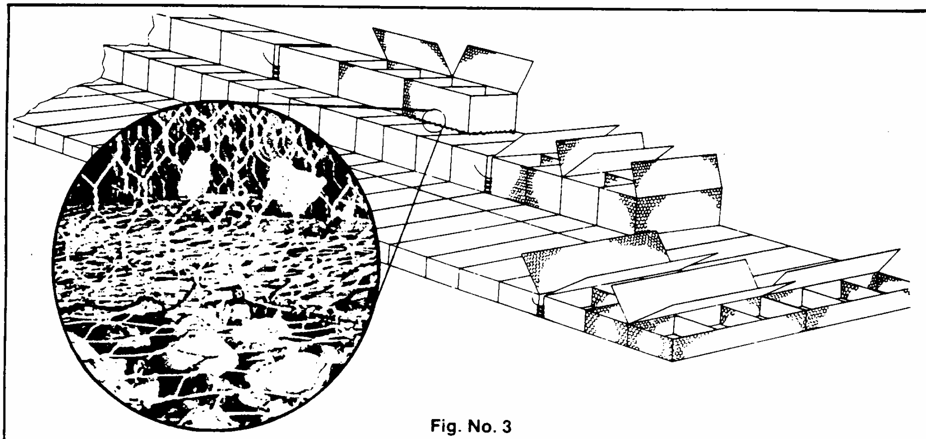

Fig. No. 3

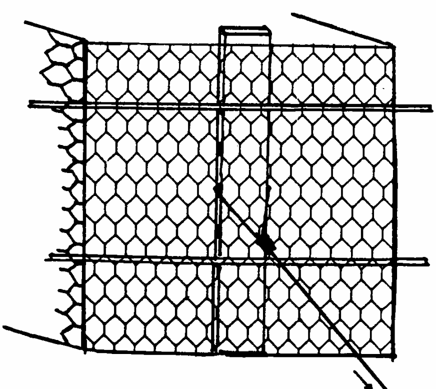

Fig. No. 4

The following method applies to three foot high gabions. Gabions should be placed empty and laced for a stretch approximately 100 linear feet. The first gabion shall be firmly anchored and tension shall be applied to the other end with a come-a-long or other means, in order to achieve the proper alignment. (See Fig. No. 4.) Anchoring can be accomplished by partially filling the first gabion with stone.

While gabions are being stretched, inspect all corners for open "V's" which will result if corners were not properly secured. Such "V's" must be closed by relacing.

Keep gabions in tension while being filled; leave the last gabion empty to allow for easily lacing the subsequent sub-assembly.

Filling:

The fill material shall consist of hard, durable stone, graded between 4 to 8 inches or as approved by the Engineer. All stone must be of size sufficient to be retained within the mesh.

Gabions shall be filled in lifts of one foot at a time. Two connecting wires shall be placed between each lift in each cell of all exposed faces and firmly wired as indicated in Figures 5 and 6. This operation is repeated until the gabions are completely filled.

It is important that the mesh forming the lid be stretched tight when the gabion is wired closed in order that there can be no movement of the fill.

For coastal structures additional requirements apply to choice of fill and to workmanship.

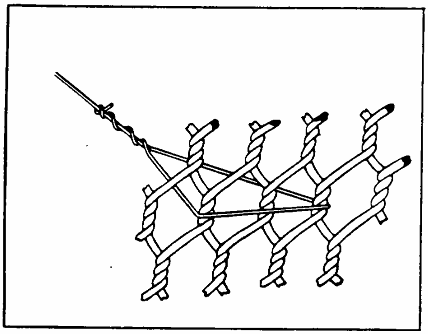

Fig. No. 5

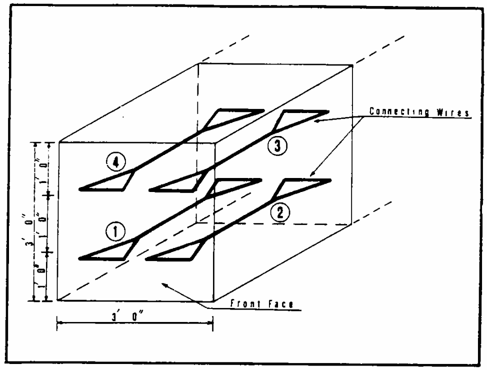

Fig. No. 6

Mechanical Filling

As most filling operations are carried out by machine it is helpful to protect the top edges of the diaphragms and end panels from being bent or folded by the stone during placement. There are several methods by which this can be achieved.

Rebars may be temporarily placed across the top edges of each mesh panel and laced to them to prevent movement.

Alternatively lengths of pliable metal may be bent into a V shape and placed over the vertical panels to deflect the stone.

During filling the stone should be dumped from the bucket when it is in the lowest practicable position.

Gabions may be filled by almost any type of earth-handling equipment: payloader, gradall, crane, conveyor or modified concrete bucket. Some manual stone adjustment, during the filling operation is required to prevent undue voids. (See Figs. No. 7 & 8).

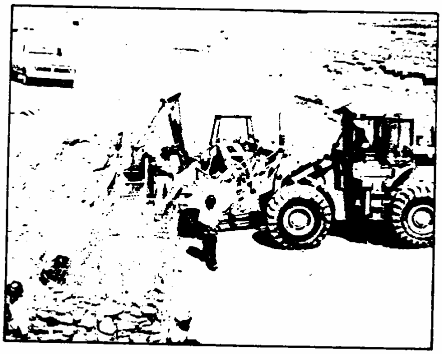

Fig. No. 8

Fig. No. 7

The exposed face(s) should be hand-placed using selected stone. This hand-placing will add to the appearance of the structure by preventing the gabions from bulging. (See Figs. No. 9 & 10).

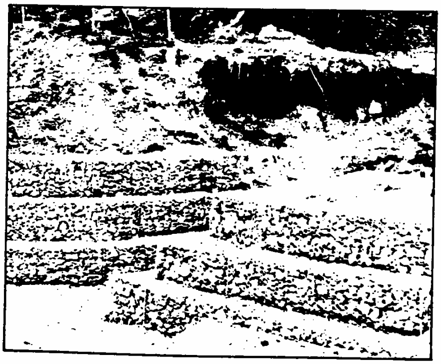

Fig. No. 9

The last lift of stone should be level with the top of the gabion to properly close the lid and provide an even surface for the next course. The mesh <u>must</u> be stretched tight at all times.

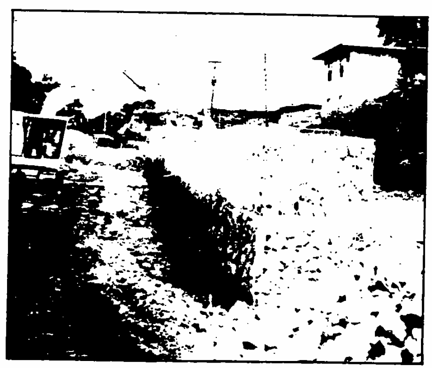

Fig. No. 10

Filling:

The fill material shall consist of hard, durable stone, graded between 4 to 8 inches or as approved by the Engineer. All stone must be of size sufficient to be retained within the mesh.

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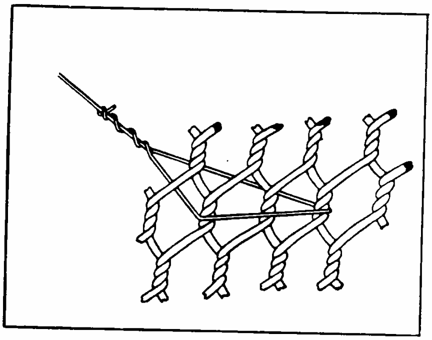

Fig. No. 5

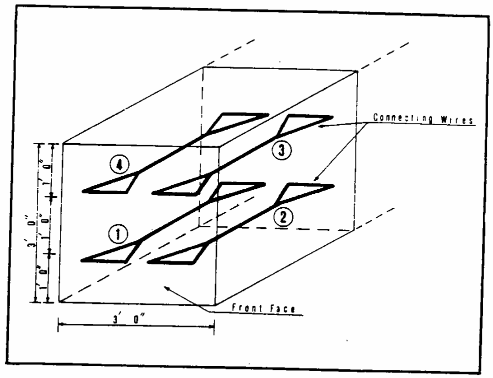

Fig. No. 6

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Alternatively lengths of pliable metal may be bent into a V shape and placed over the vertical panels to deflect the stone.

During filling the stone should be dumped from the bucket when it is in the lowest practicable position.

REVETMENTS

DESIGN DATA

The upper vertical limit of a revetment should extend above the expected high water line. The allowance for free board depends upon the velocity near the gabion revetment and, at some locations, upon the height of the waves that might be generated on the water surface. Where the stream channel is composed of sand or silt, revetments should be protected by an apron, fig. 19 or by a toe wall, fig. 18.

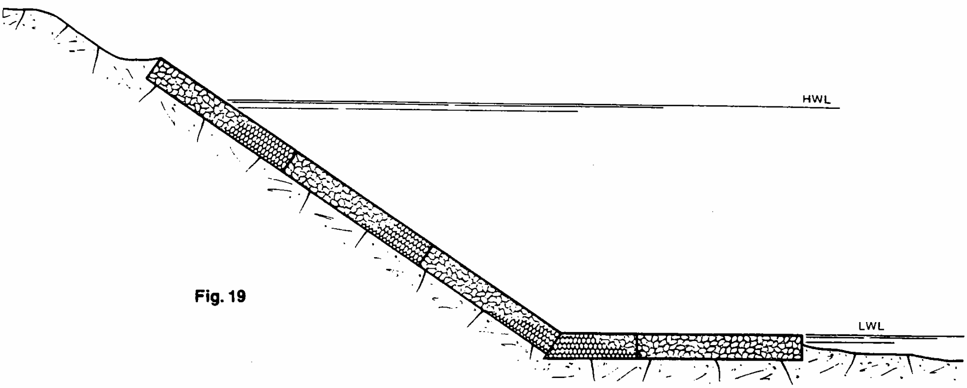
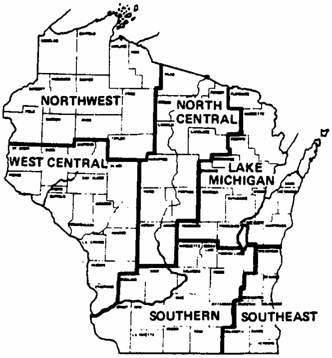


Fig. 19

Fig. 20—18" gabion revetment provides an effective and economical protection for the bridge.

Contact your district or area DNR water management representative for advice and assistance (see map). A State of Wisconsin *permit is required* for most grading and riprap projects.



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Box 309
Spooner, WI 54801-0309
(715) 635-2101

WEST CENTRAL
Call Box 4001
Eau Claire, WI 54702-4001
(715) 836-2821

NORTH CENTRAL
Box 818
Rhinelander, WI 54501-0818
(715) 362-7616

LAKE MICHIGAN
Box 3600
Green Bay, WI 54303-1208
(414) 497-4030

SOUTHERN
3911 Fish Hatchery Road
Madison, WI 53711-5397
(608) 266-2628

SOUTHEAST
Box 13248
Milwaukee, WI 53213-0248
(414) 257-6543

Water regulation & zoning

Pub. 8-3500(82)

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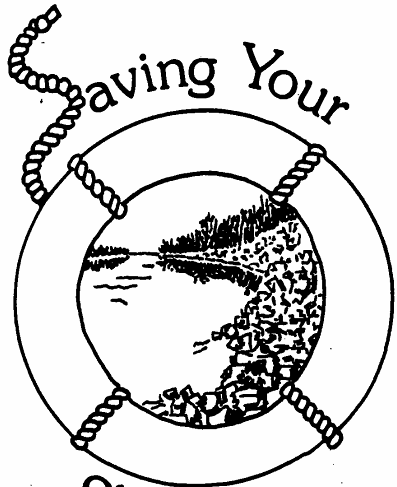
Saving Your



Shoreline

General Guidelines for Grading and Riprap

Saving Your Shoreline

There are two primary objectives of any successful riprap project: stabilizing the slope and protecting bank material from being lost to erosion.

The stability of the slope depends on four things: 1) the type of material involved; 2) the height of the embankment; 3) the slope of the embankment and 4) the external forces such as ice action and upland structures or vehicles acting on the embankment.

Is Grading the Answer?

The shoreline can often be stabilized by grading the slope to a flatter angle.

Cohesiveness of the bank material is important in determining grading requirements. The bank materials commonly encountered range from pure cohesive to pure noncohesive soils.

Sand is an example of a noncohesive material. If properly sloped and protected, it will remain stable regardless of the height of the embankment. Noncohesive materials usually need to be graded to at least 2½' horizontal to 1' vertical (a 22° slope) to remain stable with vegetative covers. Use of stone riprap may allow grading to a steeper angle, up to 1½' horizontal to 1' vertical.

Clay is an example of a cohesive material consisting of very fine particles barely distinguishable by the human eye. It is often difficult to dry out. Clay and other cohesive soils *may not remain stable* when simply graded to a uniform slope and protected by vegetation or riprap. Clay material may require terracing or retaining walls to attain stability.

Sand and clay illustrate the two stability extremes you may expect to encounter. The material you will be working with will usually be a mixture, with stability properties somewhere between sand and clay.

A prime indicator of grading requirements is the immediately surrounding area. If an adjacent embankment is stable at a given slope, chances are that your bank will be stable if graded to a similar slope.

Choosing Your Protection

Once you have decided on a grading plan (if necessary), you will need to determine the type of protection required to prevent your shoreline from eroding. Rock riprap is a common, generally low cost choice which can yield excellent results.

The idea behind a riprap project is to build an armored filter which traps the bank material and prevents it from being washed away. Ideally the riprap should be layered from a fine material against the bank to an armor layer of large stone that water and ice will not be able to move around. The texture of the existing bank material should influence the gradation of your filter. If your bank material is clay (with a very small particle size), you should start with a layer of a fine sand material followed by a layer of coarser sand and gravel, followed by a layer of stone. Remember, each succeeding layer should be just coarse enough to ensure that the underlayer cannot move through it. If your bank material is a coarse sand, you may be able to use one base course of gravel followed by a layer of riprap. In most cases a base course or filter layer should be used.

Synthetic filter cloths can be used instead of a conventional granular base course. Although it may be more expensive than sand and gravel filter material, ease of placement and superior performance can justify the increased cost.

The armor layer should be well graded but free from fine material. Following are three suggested gradations for riprap designed for light, medium and heavy protection. In each of the gradations, the suggested percentage of stone size to be used for the total project is shown in the right column.

Size of Stone	% of Stone Size to be Used
Light Protection	
2 lb. (3" diameter) or smaller	10%
2 lb. (3" diameter) - 25 lb. (8" diameter)	40%
25 lb. (8" diameter) - 60 lb. (11" diameter)	30%
60 lb. (11" diameter) - 100 lb. (13" diameter)	20%
Medium Protection	
20 lb. (0.6' diameter) or smaller	10%
20 lb. (0.6' diameter) - 200 lb. (1.3' diameter)	40%
200 lb. (1.3' diameter) - 500 lb. (1.8' diameter)	30%
500 lb. (1.8' diameter) - 700 lb. (2.0' diameter)	20%
Heavy Protection	
40 lb. (0.8' diameter) or smaller	10%
40 lb. (0.8' diameter) - 700 lb. (2.0' diameter)	40%
700 lb. (2.0' diameter) - 1400 lb. (2.5' diameter)	30%
1400 lb. (2.5' diameter) - 2000 lb. (3.0' diameter)	20%

The degree of protection needed will depend upon the body of water involved.

To withstand external forces the stone used should generally be hard, durable and angular. There should be no elongated stones where the longest dimension is more than three times the shortest dimension. Round stones tend to roll, and may fail to adequately protect a shoreline. Since they break down readily, shale, soft sandstones and organic material should be avoided.

Putting Your Protection in Place

Riprap can be placed either by hand or machine or by simply dumping the stone. Experience has shown that dumping is the most effective method. Dumping seems to do a much better job of integrating the stone and forming a continuous blanket of protection, provided the riprap is not dumped down long embankments. In rolling down embankments, the material separates into pockets of large and small stone, preventing the riprap from protecting the bank to its fullest capacity. Dumped ripraps usually require some additional shaping with heavy equipment.

Riprap should be placed no steeper than 1½' horizontal to 1' vertical. Flatter slopes will be more stable, but will require more stone.

In order for the riprap to remain stable, care must be taken to ensure stability of the starting and ending points along the shoreline. If the starting and ending points are not stable, failure of the riprap structure can occur through flanking (undercutting) from the ends to the center. Often the area surrounding the proposed riprap site proves to be unstable. In such cases, it is recommended that the ends of the riprap curve landward in order to prevent the structure from being flanked.

In addition to ensuring stability of the ends along the shore, anchoring the riprap to the bed of the waterway should be considered. Three methods of anchoring the riprap into the bed material are shown here.

Riprap must follow existing shoreline contours as nearly as possible. Property lost to gradual erosion may not be reclaimed. Protection should be considered to prevent further erosion.

Finishing Your Riprap

After the riprap has been placed, it will be necessary to revegetate disturbed, unprotected areas. A grass seed mixture with a large proportion of quick germinating annual or perennial grass is recommended. Occasional mowing is required to promote good sod development. Types of vegetative cover other than grasses are available for steep slopes which would be difficult to mow. For guidance on seed mixtures contact your local representative of the U.S. Department of Agriculture Soil Conservation Service

Before You Begin Work . . .

A permit may be required from your local zoning administrator and/or the Army Corps of Engineers.

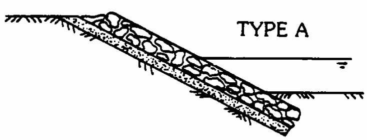
If your project is in an unincorporated area, contact the county zoning office (usually in the courthouse). In a city or village, contact the building inspector or local zoning office.

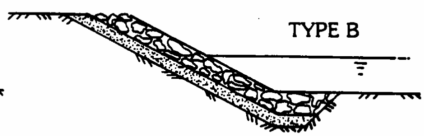
Contact the Regulatory Functions Branch of the Army Corps of Engineers:

St. Paul District, Army Corps of Engineers
1135 U.S. Post Office & Custom House
St. Paul, MN 55101
(612) 725-7712

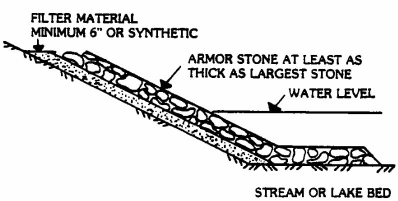
ANCHORING YOUR RIPRAP

RECOMMENDED FOR GENERAL USE

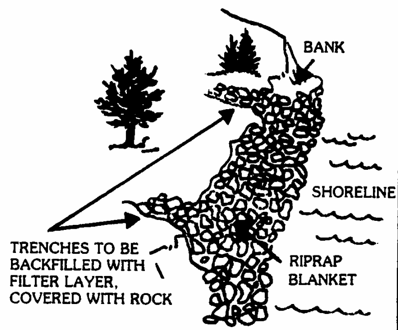




PROTECTION ON LARGE WATERWAYS



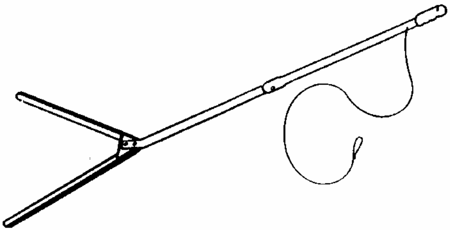
TO PREVENT FLANK EROSION



AQUA WEED CUTTER

T.M.

PATENT PENDING



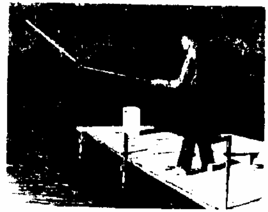
THROW IT OUT - PULL IT IN

The *Aqua Weed Cutter* is easy to use. Just throw the *Aqua Weed Cutter* from shoreline, pier or boat and pull in slowly using short jerky strokes. Underwater weeds pop up to the surface like a cork. When used regularly the *Aqua Weed Cutter* will keep beaches, swimming areas, boat slips, piers, etc., free of weeds.

No need for expensive and potentially harmful chemicals. A one time application of chemicals will pay for the *Aqua Weed Cutter* which with proper care and use can be used for many years.

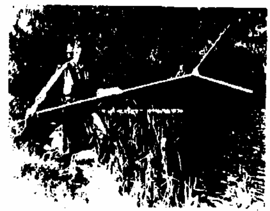
The *Aqua Weed Cutter* can be used about 3 weeks after the ice melts and whenever weeds begin to reappear.

USE FROM PIER



The *Aqua Weed Cutter* cuts a 52" path through any weeds growing on the bottom of lakes or ponds.

USE FROM SHORE



Just throw the *Aqua Weed Cutter* from shore and keep swimming areas weed free for continual enjoyable use.

I-4. Hand macrophyte cutter.

353

ECONOMY

The *Aqua Weed Cutter* will save you money because of its sturdy construction and it requires very little maintenance. It will last for years, taking the place of expensive chemicals.

EFFICIENCY

The *Aqua Weed Cutter* will save time because with continuous use, weeds will not decay on the bottom, preventing less weed growth.

ONLY

$ 59.95

PLUS $3.00 SHIPPING & HANDLING

INDIANA RESIDENTS ADD $3.00 SALES TAX

VISA & MASTER CARD ACCEPTED

LIMITED WARRANTY

The manufacturer warrants the workmanship and materials in the *Aqua Weed Cutter* for a period of 90 days from the date of purchase. In the event of defective parts, return entire unit in original box to manufacturer along with sales receipt. Defective parts or entire unit will be replaced at the discretion of manufacturer.

JL INDUSTRIES, INC.

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WATER WEED PROBLEMS?

ELIMINATE THEM WITH THE AMAZING

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